ISSN No:-2456-2165

Effect Of 1-Methylcyclopropene Concentration, Storage Temperature and Packaging on the Postharvest Quality of Mango (*Mangifera Indica* L.) Fruit Cv. Broken and Dausha

Gabriel Hungwa Atoo[1,*], Simon Terver Ubwa [1, 2], Joseph Alakali [2], Benjamin Asen Anhwange [1, 2]
Qrisstuberg Msughter Amua [1, 3]
[1]Department of Chemistry, Benue State University, Makurdi, Nigeria
[2]Center for Food Technology and Research, Benue State University, Makurdi, Nigeria
[3]Department of Chemistry, Joseph Saawuan Tarkaa University, Makurdi

Abstract:- The mango (Mangifera indica L.) is a climacteric fruit and manifests high postharvest losses due to its high perishable nature and requires special postharvest treatments to extend its shelf life. The study was undertaken to determine the effect of 1-methylcyclopropene (1-MCP) concentration, packaging material, storage temperature and time on the postharvest quality attributes of two mango cultivars namely Broken and Dausha grown in Gboko, Benue State, Nigeria. The fruits were harvested at green-mature stage and were treated with 1-methylcyclopropene (1-MCP) (0, 1000, 3000 and 5000 ppb) in closed air tight plastic containers for 24 h. The fruit samples were divided into two, one part was packaged in paperboard and another part unpackaged. The samples were stored for 90 d at 11, 13, 15 and 29 ºC (ambient) respectively. Treatments were laid out in factorial arrangement in randomized complete design (RCD) with three replications. The results showed that decay/chilling injury, colour change, firmness, total carotenoids (TC), vitamin C, pH, titratable acidity (TTA), total soluble solids (TSS) and TSS/TTA ratio were significantly ($p<0.05$) affected by 1-MCP treatment, paperboard packaging, storage temperature and cultivar throughout the storage period. The 1-MCP treated and packaged fruits showed better performance, retaining quality in all physiological ripening parameters as well as reduced senescence up to 90 d at the lowest storage temperature of 11 ºC and highest 1-MCP concentration of 5000 ppb. The untreated and unpackaged fruits on the other hand stored only for 15 d at all the temperatures studied. In terms of variety performance, Dausha mangoes recorded low fruit decay and maintained remarkable quality up to the end of 90 d in packaged paperboard at 11 ºC while Broken stored for 75 d under the same conditions. The research findings show great potential of reducing postharvest loss of Dausha and Broken mango cultivars in Benue State thereby boosting the economy of mango farmers in the State.

Keywords:- *1-methylcyclopropene, Postharvest losses, Mango fruit, Paperboard Packaging, Storage temperature.*

I. INTRODUCTION

Most of our food consists of plant based agricultural produce, which are usually seasonal and spoil quickly. To make food available throughout the year, preservative methods have been developed to prolong the storage life of foods. The spoilage process can be delayed by adding preservatives, optimizing storage conditions or applying modern techniques [1].

Fruit have health benefits for consumers due to their content of fibre, vitamins and antioxidant compounds [1]. However, for the antioxidant compounds there are changes in their composition during harvesting, preparation (fresh-cut fruit) and storage and therefore, have to be preserved. Fruit consumption has been reported to contribute to the prevention of degenerative processes, particularly lowering the incidence and mortality rate of cancer and cardio-cerebro-vascular diseases [2]. They also contain phytochemicals which act against oxidative reactions in the human body and are rich source of flavanones. Fruit have been shown to possess several physiological properties which can help inhibit cell proliferation and promote cell differentiation [3].

However, due to the perishable nature of fruit, high post-harvest losses occur immediately after harvest, during distribution and marketing, due to lack of cold storage facilities on the farms, improper handling and inadequate processing/preservation methods [4]. Storage and preservation technologies have now been utilized to transform these perishable fruit into safe, delicious and stable products that can be consumed all year round, and transported safely to consumers all over the world.

Nowadays almost all food products have preservatives which are either natural or artificial. The purpose is generally to preserve the natural characteristics of the food and to increase its shelf life as well as inhibit natural ageing and discolouration that do occur during food storage and preservation such as the enzymatic browning reaction in fruits after they are cut [5].

Natural methods of preservation are usually aimed at excluding air, moisture, and microorganisms, or at providing environments in which organisms that might cause spoilage cannot survive [6]. Natural ways of food preservation can be done by boiling, freezing, pasteurizing, dehydrating, smoking

ISSN No:-2456-2165

and pickling [7]. Sometimes sugar is combined with alcohol for preservation of food products and this inhibits efficiently the growth of bacteria in food [8].

Food preservation is also achieved through artificial methods including, nuclear radiation, vacuum packing, chemical preservative and hypobaric packing. Chemical preservatives such as sodium benzoate, benzoic acid, sodium sorbate, potassium sorbate, sodium nitrite are used as antimicrobial agents that inhibit the growth of bacteria, moulds and other microorganisms in food [9]. Some substances are used as antioxidants (they act as free radical scavengers) in food. These are vitamin E, vitamin C, pine bark extract, grape seed extract, sodium erythorbate, sodium diacetate, sodium succinate, sodium dehydroacetate, succinic acid and ascorbic acid, parabens, erythorbic acid and proplyphenols [10]. Some chelating agents such as disodium ethylenediaminetetraacetic acid (EDTA), polyphosphates and citric acid also work well as preservatives. Monosodium glutamate (MSG), disodium guanylate and disodium inosinate are used as food flavouring agents [11]. These synthetic chemicals and organic compounds used as food preservatives are the most effective for a longer shelf life and stop or delay the growth of bacteria, suppress the reaction when food comes in contact with oxygen or heat, they also prevent the loss of some essential amino-acids and vitamins that enhance the food flavours and colours [12].

The organic compound 1-methylcyclopropene (1-MCP) is widely used in delaying ripening of climacteric fruit by competing for the binding site of ethylene with its receptors and, in doing so, inhibiting the activation of the ethylene signal transduction pathway. Postharvest application of 1-MCP delays or decreases: softening, internal browning, respiration rate and ethylene production in fruit [13].

1-MCP does not leave any residues either on or inside the fruit and in the environment [14]. The structure consists of a simple carbon and hydrogen molecule. After it attaches itself to the ethylene receptor site, 1-MCP is broken down by the fruit's natural process and biodegrades into simple molecules containing carbon, hydrogen and oxygen which are naturally present in the atmosphere ([15]. Its safety, toxicity and environmental profiles with regard to humans, animals and environment have been reported, approved and registered in 1999 by the United State Environmental Protection Agency (US-EPA) and is sold under the trade name of SmartFresh [16]. In each country approval is for specific crops, and among those (depending on the country) are apple, apricot, avocado, carrot, kiwifruit, mango, melon, nectarine, papaya, peach, pear, pepper, persimmon, pineapple, plantain, plum, squash, tomato and tulip bulbs.

At present, there has been increasing research interest concerning the preservation, packaging and storage of climacteric fruits using 1-MCP throughout the world. Nonetheless, this global research on the use of 1-MCP to preserve *Mangifera indica L* had been on cultivars that are not found in Nigeria and most specifically in Benue State. In Nigeria, there is limited information and experience in the postharvest handling of mangoes in general and particularly in the use of 1-MCP as postharvest technology to extend the shelf life of mangoes. Also, there have been no standard packaging systems in Nigerian mango industry. Hence, there is dearth of information about the performance of our local mango cultivars under standard packaging system during extended storage/shipping conditions. So far, there are no available literatures in this area concerning the use of 1-MCP as a postharvest tool on mango cultivars produced in Nigeria. Therefore, the present research was initiated to evaluate the effective use of 1-MCP in managing postharvest loss of Broken and Dausha mango varieties grown in Benue State, Nigeria.

II. MATERIALS AND METHODS

A. Study Area

The study area Gboko, lies within latitude 6^0 28'' to 8^0 13'' N and longitude 8^0 04'' to 9^0 16'' E. It is located in the North Central Zone of Nigeria. This area produces the studied mango fruit varieties in very large quantities.

B. Experimental Design

The experiment was conducted in the months of May through August 2018. Two mango cultivars (Dausha and Broken) were used to investigate the effect of 1-Methylcylopropene (1-MCP) concentration, storage temperature, fruit variety, corrugated paperboard (CPB) packaging and storage time on the postharvest quality of tropical fruit. Sampling of fruit from the orchards was made in a randomized complete design (RCD) with three replications. The treatments were arranged in a factorial scheme and followed $4\times4\times2\times2$ factorial arrangement, with four levels of 1-MCP concentration (1000, 3000, 5000 ppb) and 0 ppb (as control); four conditions of storage temperature (11, 13, 15 and 29 ^oC -ambient temperature), two levels of packaging (packaged with corrugated paperboard and unpackaged) and two mango varieties (Dausha and Broken). The fruit were observed for 90 d and quality evaluation was carried out for every 15 d interval (0, 15, 30, 45, 60, 75 and 90).

C. Determination of Sample Size

The number of samples (n) for the analysis was determined using the formula below:

Number of samples (n) = $C\times T\times X\times Y\times Z$ (1)

Where C is concentration of 1-MCP in ppb (4 levels),
T is storage temperature in ^oC (4 levels)
X is cultivar (2 levels)
Y is packaging (2 levels) and
Z is number of times of analysis (6 times).
Therefore,

Sample size n = $4\times4\times2\times2\times6$ =384 samples (2)

D. Sample Collection

A sample size consisting of 384 mature green mango fruit was collected from the two orchard farms, Mtswenen Tyo farm, behind new government reserved area (GRA) and Tse Apev compound, Yandev, both in Gboko Local Government Area of Benue State using hand picking method with the stalk intact. Each cultivar was collected and labelled. The procedure for determining the stage of maturity was used with slight modification. Fruit were considered mature green when firm with no depression when thumb pressed and visual

ISSN No:-2456-2165

appearance as determined by the size, shape (fullness of cheeks), skin colour (dark green to light green) and specific gravity (ratio of mango density to the density of water) [17]. Clean open air plastic containers were used in transporting samples to the Chemistry laboratory, Benue State University, Makurdi, Nigeria. The samples were properly identified by a Botanist in the Department of Biological Science, Benue State University, Makurdi.

E. Sample Preparation

Only samples that were fresh free from disease and defects and of closed uniform maturity were chosen for the study. The fruit were thoroughly sorted, washed under running tap water and air dried in the laboratory. A total of three hundred and eighty four (384) mango fruit (92 Dausha and 92 Broken fruit) were sampled from two cultivars of mango for investigation.

F. Sample Treatment/Fumigation with 1-MCP

1-MCP was applied to the mango fruit (Broken and Dausha) on the day of harvest. Two hundred and eighty eight (288) mango fruit were labelled according to the three 1-MCP concentrations (1000, 3000 and 5000 ppb) and then grouped into three lots of ninety six (96) fruit of Broken and Dausha. These lots with equal amount of Broken and Dausha mango fruit were placed inside the corresponding labelled air-tight lidded 250 L capacity plastic containers together with a beaker containing a known amount of 1-MCP (1000, 3000 and 5000 ppb) needed to generate the required concentration of the gas. The containers were covered immediately and sealed after adding 20 mL of distilled water into the beaker to release the 1-MCP gas and were kept at 18 ^{o}C for 24 h for the reaction to complete. The other ninety six (96) fruit (control) were labelled and kept on the laboratory bench for 24 h to be stored at the same time with the fumigated fruit.

G. Packaging and Storage

A total of three hundred and eighty four (384) fruit were used. One hundred and ninety two (192) fruit (both Broken and Dausha) were packaged in thirty two (32) corrugated paperboard boxes consisting of six (6) fruit per box according to 1-MCP concentrations. The other one hundred and ninety two (192) fruit were stored without packaging. All the fruit were stored for ninety (90) days at 11, 13, 15 and 29 ^{o}C (ambient temperature) for quality evaluation.

H. Quality evaluation

The quality evaluation was performed six times at day 15, 30, 45, 60, 75 and 90 of storage.

a) Decay/Chilling Injury

Decay/Chilling injury during the experiment was estimated by using the following formula [18].

$$\text{Decay/Chilling injury (\%)} = \frac{\text{Number of affected fruit per treatment}}{\text{Total number of fruit per treatment}} \times 100 \quad (3)$$

b) Colour

Colour of the skin and flesh were measured using a Colorimeter (Model: Precise Colour Reader WR-10). Mango samples were cut longitudinally and the readings were taken in the central region of the slices. The system L*, a*, b*, were employed, where L* is the lightness of the colour (for black L* =0 and for white L* =100) .The a* axis varies from green (-a*) to red (+a*) and the b* axis varies from blue to yellow (+b*) [19].

c) Firmness

Firmness was measured using a penetrometer (Model: PIVOT 81-PVO103). A thin patch of skin was removed along the cheek side or equatorial position of the fruit. The fruit was placed on a firm surface for testing pressure. Firmness was measured using a penetrometer with the 5 mm diameter stainless steel probe. The maximum value recorded by the probe in Newton (N), while passing through the fruit to a depth of 10 mm without hitting the seed was used as firmness of the fruit. The process was repeated on the other cheek and the average value recorded [18].

d) Total carotenoids

Exactly 2 g of crushed and homogenised pulp was mixed with 50 mL of ternary solvent (hexane/ethanol/acetone) in the ratio of 50: 25: 25 and agitated for 30 min. After filtration, the mixture was placed in a separatory funnel and washed three times with 25 mL of distilled water to remove the ethanol and acetone. The standard curve for all spectrophotometric readings was obtained using absorbance readings from standard β-carotene capsules dissolved in hexane at concentrations of 0.00 to 0.06 mg/mL. The absorbance was measured at 450 nm, using a UV-Visible spectrophotometer (Model: JENWAY 7315). This wavelength corresponds to the five predominant carotenoid species (β-carotene, zeaxanthin, lycopene, lutein, β-cryptoxanthin). The calculation of β-carotene was as follows [20].

$$\beta\text{-carotene (mg/100 g)} = \frac{\textit{observed } \beta - \textit{carotene (mg/ml)} \times V \times D \times 100}{W} \quad (4)$$

Where V = total volume of extract
D = dilution factor
W = weight of sample

e) Vitamin C

Vitamin C (ascorbic acid) was determined by the method of titration using 2, 6-dichloroindophenol following Method 967.21 of AOAC [21]. Exactly 10 g of sample was mixed with distilled water and agitated for 10 min and filtered through Whatman No 4 filter paper. 10 mL of the filtrate was transferred into 250 mL conical flask and 15 mL of 21 % oxalic acid solution was added. The sample was titrated with 2 % dichloro indophenol till pink colour appeared. The results were calculated using the following formula and expressed in mg/100 g fresh weight.

$$\text{Vitamin C (mg/100 g)} = \frac{\text{titre} \times \text{dye factor} \times \text{volume made up}}{\text{volume of filtrate taken} \times \text{volume of sample}} \times 100 \quad (5)$$

ISSN No:-2456-2165

f) Titratable acidity and Ph
Total titratable acidity (TTA) was determined according to the method by Nagata and Yamashita [22]. Exactly 15 g of the mango pulp were blended with 100 mL of distilled water using an electric blender. The pH of the blended solution was measured at room temperature after calibrating the meter (Moddel: OAKTON pH/CON 510 Series) with buffers at pH 4 and 7 solutions. The blended solution was titrated with 0.1M NaOH to an end point of pH 8.2 using phenolphthalein indicator and the result was recorded in millilitres of NaOH used. Titratable acidity was calculated using the following formula:

$$\%\ TTA = \frac{mL\ of\ NaOH\ used \times 0.1M\ NaOH \times milliequivalent\ factor \times 10(}{grams\ of\ sample} \quad (6)$$

.

g) Total soluble solids
The total soluble solids (TSS) was determined using Abbe's refractometer (Model: abbe 60/DR) following Method 932.12 of AOAC [21]. Before use, the instrument's glass prism was cleaned with a cotton wool and adjusted to zero at room temperature using distilled water. An appropriate quantity (1-2 drops) of the juice from the blended fruit of each sample was placed on the prism-plate of the refractometer with the help of a glass rod after folding back the cover. A tissue paper was used in cleaning the excess juice around the prism of the refractometer. For each sample, the instrument was calibrated using distilled water. The reading on the screen was directly recorded as total soluble solids.

h) TSS/TTA ratio
The ratio of TSS/TTA was estimated by dividing the value of TSS obtained by that of TTA [21].

a. Statistical Analysis
Data was analyzed by one way analysis of variance (ANOVA) without blocking. Means separation was done using least significant difference (LSD) test for multiple means comparism. The GENSTAT statistical package was used for all analyses (The GENSTAT Release 10.3DE, PC/Windows 7, Edition 17th, VSN International Ltd, Rothamsted Experimental Station). All test of significance were at $p \leq 0.05$. Results were expressed as mean±standard deviation.

III. RESULTS AND DISCUSION

The results of the analysis of the quality parameters of Broken and Dausha treated with concentrations of 1-MCP and stored at different temperatures are presented in Tables 1-11. The physico-chemical parameters determined were: decay/chilling injury, colour (L^*, a^*, b^*), firmness (FM), total carotenoid (TC), vitamin C, pH, titratable acidity (TTA), total soluble solids (TSS) and TSS/TTA for day 15, 30, 45, 60, 75 and 90. The result showed that 1-MCP concentration, packaging, storage temperature and time significantly ($p<0.05$) affected the parameters tested. Values are presented as mean±standard deviations (SD). The number of replicate determinations (N) is six.

A. Decay/Chilling injury

The results indicate that decay/chilling injury of mango fruit were affected significantly by 1-MCP treatment, paperboard packaging, storage temperature and cultivar throughout the storage periods. At day 15, there was no significant difference ($p>0.05$) in all 1-MCP treated, packaged and non-packaged fruit except the non-treated (control) (Table 1). Decay/chilling injury accelerated from day 30 to day 90 irrespective of packaging material and 1-MCP treatment imposed. However, the 1-MCP treated mango fruit showed significant ($p<0.05$) lower rates in the decay/chilling injury as compared to the untreated. The 1-MCP (5000 ppb) treated and packaged Broken cultivar attained 91.67 % deterioration at 75 d of storage at 11 ^oC while the unpackaged samples treated at the same concentration deteriorated completely at 45 d of storage at the same temperature. On the other hand, the Dausha cultivar treated with 5000 ppb 1-MCP and packaged attained 68.25 % deterioration at 90 d, while the unpackaged samples deteriorated at 45 d at 11 ^oC. On commercial basis, modified atmosphere and low temperature storage are often combined to reduce fruit metabolism, delay decay and maintain quality. It has been reported that storing fruit at low temperatures causes chilling injury. However, 1-MCP is known to suppress disorders related to low temperature storage such as chilling injury [23].

The observed decrease in the rate of decay/chilling injury with increase in 1-MCP concentration can be attributed to the inhibition action of 1-MCP which is known to reduce endogenous and exogenous ethylene and respiration, delay ripening and senescence as well as reduced incidence of peel greasiness, core flush, mealiness and chilling injury [24, 25]. The 1-MCP may have also inhibited the activities of enzymes related to cell wall degradation, fruit browning and ethylene biosynthesis, such as polygalacturonase (PG), polyphenol oxidase (PPO),1-aminocyclopropane-1-carboxylic acid synthase (ACS) and 1-aminocyclopropane-1-carboxylic acid oxidase (ACO) [26, 27]. When ACS and ACO activities are decreased, 1-aminocyclopropane-1-carboxylic acid (ACC) synthesis and oxidation is reduced resulting in decreasing ethylene biosynthesis and consequently ethylene-induced respiration. These findings are also in line with the observations of Silva *et al*., [28], who reported that mango fruit treated with 1-MCP concentration showed reduced metabolic activities, compared to the nontreated (control). The difference in the decay/chilling injury between the two mango cultivars at the optimum 1-MCP concentration of 5000 ppb and temperature of 11 ^oC may be due to species, cultivar, physiological difference and maturity stage during harvest. This is in agreement with other researchers who stated that the efficacy of 1-MCP depends on the cultivar and fruit maturity [29].

Packaged fruit were with lower rate of percentage decay compared to non packaged fruit (Table 1). Though not all treated and packaged fruit stored up to day 90, the paperboard packaged samples showed significant differences ($p<0.01$) in reducing decay/chilling injury throughout the

ISSN No:-2456-2165

storage period. The higher relative humidity and modified atmosphere (MAP) created within the packages may have been responsible for the significant reduction in decay/chilling injury for packaged mango fruit. The result is in agreement with other researchers [28, 30, 31]. The MAP created may have caused reduced respiration and metabolic activities through depletion of oxygen and increase carbon dioxide in the paper board packaging free space. CO_2 inhibits ethylene production rates and O_2 uptake rate. An inhibition of respiration results in reduced adenosine triphosphate (ATP) production that is involved in the conversion of ACC to ethylene and also the protein phosphorylation that would have been necessary for activation of ACC oxidase [31, 32].

Generally, the decay/chilling injury increased with storage time and temperature throughout the storage period. Minimum losses were recorded at the beginning of storage and lower temperatures while maximum losses were observed towards the end of storage and at higher temperatures.

Packaging	Cultivar	Treatment (ppb)	Storage period (d)					
			15	30	45	60	75	90
Packaged	Broken	0 (control)	45.00	100.00	-	-	-	-
		1000	0.00	28.17	69.00	83.33	100.00	-
		3000	0.00	25.22	61.20	77.00	100.00	-
		5000	0.00	18.00	40.00	66.67	91.67	100.000
	Dabsha	0 (control)	14.33	86.20	100.00	-	-	-
		1000	0.00	23.00	50.00	70.00	100.00	-
		3000	0.00	17.00	41.00	62.00	78.00	89.33
		5000	0.00	9.00	24.00	40.23	65.00	68.25
Unpackaged	Broken	0 (control)	66.35	100.00	-	-	-	-
		1000	0.00	36.33	82.50	100.00	-	-
		3000	0.00	29.17	76.00	100.00	-	-
		5000	0.00	25.00	60.00	100.00	-	-
	Dabsha	0 (control)	21.10	100.00	-	-	-	-
		1000	0.00	29.17	78.00	100.00	-	-
		3000	0.00	25.00	65.00	100.00	-	-
		5000	0.00	22.00	56.00	100.00	-	-
	LSD $p \leq 0.05$)		0.34	0.01	0.03	0.01	0.01	0.01

Table 1: Decay/Chilling injury (%) of Broken and Dausha mango as affected by 1-MCP treatments, packaging and storage temperature during storage period of 90 d

- no value

B. Colour

a) L* value

The L* value which is an indicator of lightness of colour of the fruit decreased with increased 1-MCP concentration, and increased storage time resulting in more loss of the green colour and increased ripening (Table 2). The fastest change in colour was observed in the control samples, where they turned to yellow (56.46) within 15 d of storage. The drastic increase in L* value of control within a short storage period, may be attributed to the decreasing chlorophyll content of the peel with an increase in β- carotene mediated by an increase in enzyme chlorophylase and peroxidase or both as ripening progresses [33].

Statistically, there was a significant ($p<0.05$) decrease in L* values with corresponding increase in 1-MCP concentration across the storage time. That is, the higher the concentration of 1-MCP the lower the L* value and the healthier the skin quality. The lower L* value may be attributed to the property of 1-MCP in delaying skin colour change in climacteric fruit [33]. The delay in colour changes in the treated fruit may be due to the suppression of ethylene activities by 1-MCP. This result is contrary to the findings of Pauziah and

ISSN No:-2456-2165

Ikwan [34], who used 1-MCP concentrations of 2000 and 4000 ppb on Chokanan mangoes but rather had shrink and dull skin colour. The variation with the reported work may be due to differences in cultivar, 1-MCP concentrations, storage conditions and growing region.

The peel colour change (L* value) increase progressively as the temperature increases irrespective of 1-MCP concentration throughout the storage time. Lower L* values are recorded at 11 ^{o}C and higher L* values at 15 or 29 ^{o}C (Table 2) indicating low and high ripening of fruit at those temperatures respectively.

This result shows that temperature has a very important effect on the efficacy of 1-MCP. Also, low temperatures retard metabolic activities of enzymes whereas high temperatures speed metabolic activities. The result of this study is in line with other researchers who found.

Variables	Storage period (d)					
	15	30	45	60	75	90
1-MCP 0 (control)	56.46±0.02	-	-	-	-	-
1000	54.65±0.01	55.63±0.01	46.34±0.05	57.90±0.01	-	-
3000	54.33±0.00	54.46±0.03	54.49±0.03	55.60±0.02	59.68±0.00	61.20±0.03
5000	54.44±0.03	54.34±0.01	54.50±0.01	55.40±0.03	55.37±0.04	55.67±0.05
LSD (p≤0.05)	0.01	0.01	0.01	0.01	0.01	0.02
ST 11	51.41±0.00	55.36±0.02	55.49±0.03	56.22±0.10	57.10±0.06	57.28±0.01
13	53.24±0.02	57.06±0.01	61.04±0.02	-	-	-
15	55.35±0.03	57.73±0.03	-	-	-	-
29	55.56±0.01	-	-	-	-	-
LSD (p≤0.05)	0.01	0.01	0.01	*	*	*
PB packaged	53.89±0.02	55.19±0.02	55.45±0.02	56.30±0.05	57.22±0.01	57.61±0.07
Unpackaged	55.91±0.04	56.43±0.03	50.89±0.02	-	-	-
LSD (p≤0.05)	0.01	0.01	0.07	*	*	*
Cultivars	54.81±0.02	55.56±0.02	56.75±0.02	57.60±0.01	57.92±0.02	-
Broken	52.99±0.01	54.06±0.01	55.78±0.02	55.90±0.03	55.94±0.01	56.05±0.08
Dausha						
LSD (p≤0.05)	0.01	0.01	0.01	0.01	0.01	*
SE	1.42	0.97	0.27	0.09	0.12	0.50
CV (%)	1.87	8.43	1.52	3.28	4.06	4.72
Interaction	S	S	S	S	S	S
p. 1-MCP×ST	S	S	S	S	S	S
p. 1-MCP×PB	S	S	S	S	S	S
p.1-MCP×Cultivar						

ISSN No:-2456-2165

Table 2: Peel colour L* of Broken and Dausha mango as affected by 1-MCP concentration (ppb), storage temperature (°C), packaging material and cultivar during storage period of 90 d.

Variables		Storage period (d) 15	30	45	60	75	90
1-MCP	0 (control)	10.86±0.02	-	-	-	-	-
	1000	-8.13±0.04	13.02±0.01	-10.40±0.03	10.23±0.03	-	-
	3000	-7.85±0.05	-1.59±0.01	-10.00±0.05	7.03±0.02	4.36±0.04	3.93±0.04
	5000	-5.87±0.02	-1.59±0.01	-6.49±0.02	1.29±0.01	1.93±0.03	1.47±0.02
LSD (p≤0.05)		0.55	0.26	0.01	0.01	0.01	0.03
ST	11	-4.45±0.05	-5.36±0.03	-6.62±0.03	5.25±0.01	4.30±0.08	6.05±0.01
	13	-6.11±.02	-5.38±0.04	-11.30±0.01	-	-	-
	15	-1.92±0.01	16.86±0.01	-	-	-	-
	29	20.22±0.04	-	-	-	-	-
LSD (p≤0.05)		0.55	0.26	0.01	*	*	*
PB	Packaged	-8.05±0.03	-2.32±0.02	-11.56±0.04	10.12±0.02	9.05±0.01	9.02±0.03
	Unpackaged	8.30±0.04	12.74±0.01	-6.36±0.01	-	-	-
LSD (p≤0.05)		0.39	0.22	0.01	*	*	*
Cultivars	Broken	12.08±0.05	18.18±0.03	10.88±0.03	12.24±0.02	1.05±0.03	-
	Dausha	-4.27±0.02	6.88±0.04	7.04±0.05	6.12±0.01	5.24±0.04	5.15±0.01
LSD (p≤0.05)		0.39	0.22	0.01	0.01	0.01	*
SE		1.36	4.31	1.78	3.34	4.28	5.06
CV (%)		16.6	10.21	6.90	6.73	5.35	7.89
Interaction							
p.1-MCP×ST		NS	NS	S	S	S	S
p.1-MCP×PB		NS	NS	S	S	S	S
p.1-MCP×Cultivar		NS	NS	S	S	S	S

1-MCP, 1-Methylcyclopropene concentration in ppb; ST, storage temperature in °C; PB, paperboard packaging; LSD, least significant difference at 5% level; *Values not compare with any at this level; - no value; Values are presented as Means±Standard deviations (n=6); S, significant at $p<0.05$ level that the efficacy of 1-MCP depend on concentration and temperature [25].

Generally, peel colour change of mango fruit was significantly affected ($p<0.05$) by 1-MCP treatment, storage temperature, paperboard packaging and cultivar throughout the storage period. Packaged and unpackaged samples showed no significant difference ($p>0.05$) in peel colour on day 45.

Table 3: Flesh colour a* of Broken and Dausha mango as affected by 1-MCP concentration (ppb), storage temperature (oC), packaging and cultivar during storage period of 90 d

1-MCP, 1-Methylcyclopropene concentration in ppb; ST, storage temperature in °C; PB, paperboard packaging; LSD, least significant difference at 5% level; - no value; *Values not compare with any at this level. Values are presented as Means±Standard deviations (n=6); NS, nonsignificant at $p>0.05$ level; S, significant at $p<0.05$ level among the two mango varieties studied. However, packaged fruit recorded low peel colour change (50.89) while unpackaged fruit showed higher peel colour change on other storage days (55.45). The unpackaged fruit may have more access to oxygen which is needed in the synthesis and oxidation of ethylene, metabolism of sugars and respiration of fruit, thus resulting to colour change from green to yellow than the paper board packaged mango samples. On the other hand, the delay in colour changed of packaged mango fruit may be due to retarded respiration and ethylene biosynthesis as a result of modified atmosphere (depletion in O_2 and accumulation of CO_2) in the packaging material. This result is in line with the earlier report by Cocozza *et al.*, [30] who observed a delay in skin colour change in 'Tommy Atkins' mangoes due to modified atmosphere.

There was a significant interaction effect ($p<0.05$) between 1-MCP concentration and storage temperature, 1-MCP concentration and packaging material, 1-MCP concentration and cultivar on the peel colour L* change of Broken and Dausha.

b) a* value

Varied values of the skin redness (a*) of Dausha and Broken were recorded during the storage period (Table 3). This might be because of differences in physiological composition and cultivar difference among the mango fruit samples. The effects of 1-MCP concentration, storage temperature, packaging and cultivar were nonsignificant ($p>0.05$) on redness values for Broken and Dausha for day 15 and 30 but significant ($p<0.05$) at day 45, 60, 75 and 90. There was no shift in the negativity to positivity, indicating inhibition of ripening, in the 1-MCP treated samples. However, the control fruit started shifting from negative (-a*) values towards positive (+a*) within 15 d of storage (Table 3) indicating rapid degradation of chlorophyll and accumulation of carotenoids [33].

ISSN No:-2456-2165

The results showed that 1-MCP treatment could delay the colour change of the fruit's flesh during storage. Both 3000 and 5000 ppb treatments maintained low flesh colour index during storage and changed progressively from green to red at the end of storage period without much difference between them. Similar to the result of skin colour, the flesh colour changes in Broken and Dausha may have been caused by chlorophyll degradation and carotenoids synthesis [33]. The delay in flesh colour changes due to 3000 and 5000 ppb treatment might be due to the ability of the higher doses of 1-MCP in inhibiting the biosynthesis of carotenoid, water soluble anthocyanins as well as betalains which impart red colour during fruit ripening [35]. The ability of the 1-MCP treated fruit to eventually develop acceptable red colour (ripening) after storage is an indication that the full nutritional benefits of carotenoids of the fruit are not lost at the end of storage period.

There was significant effect ($p<0.05$) on redness values among the two cultivars except on day 15 and 30 (Table 3). Broken was with higher redness values while Dausha was with lower redness values with some having negative value. The difference in redness values may be as a result of genetic composition and low values may also be due to the inhibition action of 1-MCP at those concentrations.

	Storage period (d)					
Variables	15	30	45	60	75	90
1-MCP 0(control)	57.95±0.04	-	-	-	-	-
1000	51.60±0.01	55.92±0.01	56.76±0.01	56.79±0.02	-	-
3000	51.48±0.01	55.79±0.03	56.22±0.03	56.05±0.01	46.61±0.03	46.67±0.02
5000	51.20±0.03	55.39±0.02	55.48±0.05	56.53±0.02	45.63±0.05	45.62±0.02
LSD($p\leq0.05$)	0.01	0.01	0.01	0.01	0.02	0.02
ST 11	49.67±0.03	52.80±0.04	55.90±0.02	52.98±0.01	49.28±0.07	47.22±0.03
13	51.69±0.02	56.78±0.01	43.83±0.03	-	-	-
15	57.23±0.03	59.52±0.03	-	-	-	-
29	57.34±0.01	-	-	-	-	-
LSD ($p\leq0.05$)	0.01	0.01	0.01	*	*	*
PB Packaged	51.82±0.05	55.63±0.03	53.33±0.04	51.05±0.02	50.34±0.01	49.86±0.04
Unpackaged	55.89±0.02	56.44±0.02	40.25±0.02	-	-	-
LSD ($p\leq0.05$)	0.01	0.00	0.01	*	*	*
Cultivars Broken	56.48±0.02	60.29±0.02	41.16±0.01	50.98±0.01	51.96±0.03	-
Dausha	51.23±0.01	51.77±0.01	52.43±0.04	48.73±0.01	50.18±006	50.05±0.03
LSD ($p\leq0.05$)	0.01	0.00	0.01	0.01	0.02	*
SE	0.02	0.04	0.60	0.03	0.70	0.01
CV (%)	0.00	0.01	0.30	0.00	0.05	0.91
Interaction						
p.1-MCP×ST	S	S	S	S	S	S
p.1-MCP×PB	S	S	S	S	S	S
p.1-MCP×Cultivar	S	S	S	S	S	S

Table 4: Flesh colour b^* of Broken and Dausha mango as affected by 1-MCP concentration (ppb), storage temperature (°C), packaging material and cultivar during storage period of 90 d

1-MCP, 1-Methylcyclopropene concentration in ppb; ST, storage temperature in °C; PB, paperboard packaging; LSD, least significant difference at 5% level; - no value; *Values not compare with any at this level. Values are presented as Means±Standard deviations (n=6); S, significant at $p<0.05$ level

The effect of paperboard packaging on redness values among the two mango cultivars was nonsignificant ($p>0.05$) on day 15 and 30 but significantly different ($p<0.05$) on day 45 to 90 (Table 3). Packaged fruit recorded lower redness values while unpackaged fruit recorded comparatively higher redness values. The lower values may be as a result of the modified atmosphere (MAP) created (depletion of oxygen with increased carbon dioxide) in the packaging material which results to decreased metabolic activities. The effect of storage temperature on redness among the two mango cultivars was nonsignificant ($p>0.05$) on day 15 and 30 (Table 3) but significantly different ($p<0.05$) on day 45 to 90. The redness increased with increasing temperature with the values changing to positive at ambient temperature (29 °C). This implies that low temperature retards metabolic activities of enzymes that degrade chlorophyll [35].

The interaction effect between 1-MCP concentration and storage temperature, 1-MCP concentration and packaging, 1-MCP concentration and cultivar on redness of Broken and Dausha mangoes was not significantly different ($p>0.05$) on day 15 and 30 but significantly different ($p<0.05$) from day 45 to 90 (Table 3).

c) b* value

The 1-MCP concentrations, storage temperature, packaging, storage time and their interactions, significantly ($p<0.05$) affected the yellowness (b* value) of mango fruit (Table 4).Yellowness colour of the matured green fruits which was initially noticed on

ISSN No:-2456-2165

the 15th day, increased with storage period and temperature, attaining a maximum value on day 60. Among all the treatments imposed, 3000 and 5000 ppb delayed the increase in yellowness the most. After the first 15 d of storage, yellowness colour of the control increased sharply due to the fact that both exogenous and endogenous ethylene were not inhibited by 1-MCP which paved the way for drastic degradation of chlorophyll and carotenoids synthesis as noticed from the results; higher concentrations of 1-MCP (3000 and 5000 ppb) maintaining the low colour index during storage. The dependency on concentration for 1-MCP efficacy has also been reported previously by other researchers [36, 37].

The yellowness of mango fruit increased with storage temperature and decreases with storage time (Table 4). Storage temperature significantly affected ($p<0.05$) flesh colour yellowness of mango fruit throughout the storage period. Mango fruit stored at lower temperatures (11 °C) showed low flesh yellowness changes while those stored at higher temperatures (29 °C ambient) recorded higher flesh colour yellowness values throughout the storage period. Yellowness values differed significantly ($p<0.05$) from day 15 to the end of storage period. The yellowness in mango fruit is due to the presence of carotenoids which are highly susceptible to degradation by heat, low pH and light exposure [38]. The change from the initial b* value of 44.21 and 45.34 for Broken and Dausha to 56.48 and 51.23 respectively may have been due to increase in corresponding storage temperatures from 15 °C to 29 °C. It has been reported that low storage temperatures reduce the rate of enzymatic activities in fruit [39, 40]. The study shows that low temperatures (11 °C) are best for storing the mangoes under study.

Variables		Storage period (d) 15	30	45	60	75	90
1-MCP	0 (control)	0.89±0.01	-	-	-	-	-
	1000	1.46±0.04	0.59±0.02	0.73±0.03	0.45±0.02	-	-
	3000	2.30±0.02	1.80±0.01	1.90±0.05	1.11±0.01	0.18±0.04	0.85±0.06
	5000	3.78±0.00	3.45±0.04	2.07±0.01	1.96±0.01	1.47±0.03	1.17±0.02
LSD ($p\leq0.05$)		0.01	0.01	0.01	0.02	0.02	0.02
ST	11	2.87±0.02	2.89±0.02	2.15±0.00	1.89±0.03	1.63±0.01	1.25±0.07
	13	1.35±0.00	1.07±0.02	0.75±0.02	-	-	-
	15	0.14±0.01	0.09±0.01	-	-	-	-
	29	0.09±0.00	-	-	-	-	-
LSD ($p\leq0.05$)		0.01	0.01	0.01	*	*	*
PB	packaged	1.99±0.03	1.88±0.02	1.55±0.02	1.42±0.01	1.31±0.03	1.21±0.04
	unpackaged	0.76±0.04	0.72±0.01	0.56±0.01	-	-	-
LSD ($p\leq0.05$)		0.01	0.01	0.01	*	*	*
Cultivar	Broken	1.85±0.05	1.75±0.01	0.71±0.04	0.57±0.02	0.13±0.00	-
	Dausha	3.87±0.03	3.35±0.03	2.02±0.03	1.77±0.01	1.46±0.03	1.18±0.01
LSD ($p\leq0.05$)		0.01	0.00	0.01	0.02	0.02	*
SE		0.01	0.50	0.03	0.93	0.01	0.04
CV (%)		0.70	0.81	0.60	2.04	0.68	0.50
Interaction							
p.1-MCP×ST		S	S	S	S	S	S
p.1-MCP×PB		S	S	S	S	S	S
p.1-MCP×Cultivar		S	S	S	S	S	S

Table 5: Firmness (N) of mango fruits as affected by 1-MCP concentration (ppb), storage temperature (°C), packaging and cultivar during storage period of 90 d

1-MCP, 1-Methylcyclopropene concentration in ppb; ST, storage temperature in °C; PB, paperboard packaging; LSD, least significant difference at 5% level; - no value; *Values not compare with any at this level. Values are presented as Means±Standard deviations (n=6); S, significant at $p<0.05$ level

The effect of packaging material on the flesh yellowness of Broken and Dausha mango samples was significantly different ($p<0.05$) throughout the storage period (Table 4). The unpackaged mango fruit exhibited higher flesh yellowness while the packaged fruit had lower flesh yellowness. The lower colour b* value recorded in the packaged fruit may have been because of the modified atmosphere in the packaging material. Similar results were also reported [30, 32] where packaged mango fruit showed delayed and low flesh yellowness.

There was significant difference ($p<0.05$) in flesh yellowness of Broken and Dausha throughout the storage period (Table 4). Broken exhibited high flesh yellowness while Dausha recorded low flesh yellowness. There was a general increase in colour flesh yellowness for the first 30 d and, thereafter a gradual decreased in the rest of storage days.

ISSN No:-2456-2165

The variation in flesh yellowness value between Broken and Dausha may be due to the difference in genetic makeup of horticultural crops.

The interaction effect between 1-MCP concentration and storage temperature, 1-MCP concentration and packaging material, 1-MCP concentration and cultivar on flesh yellowness of Broken and Dausha mango fruit was significantly different ($p<0.05$) throughout the storage period (Table 4).

C. Firmness

The 1-MCP treatments, storage temperature, paperboard packaging and cultivars had significant effect ($p<0.05$) on firmness of mango fruit throughout the storage periods (Table 5). There was significant difference in firmness between the control and 1-MCP treated fruit during storage regardless of 1-MCP concentrations used. Irrespective of storage period, fruit treated with 3000 and 5000 ppb had higher firmness values when compared to control. The firmness of the control fruit dropped drastically from –4.62 to 0.89 N by day 15 of storage as the fruit reached the texture of edible condition.

The rapid decline in firmness of the control samples may be due to ethylene action which accelerated the softening of the mango fruit. Generally, fruit softening is associated with cell wall disassembly, during which pectin and hemicelluloses in cell walls undergo solubilization and depolymerization which contribute to cell wall loosening [41]. These wall modifications are likely brought about by the action of pectolytic enzymes during ripening such as polygalacturonase (PG), pectin esterase (PE) or galactosidase [42]. The reduction of softening enzyme activities following 1-MCP treatments has been reported by several researches. Opiyo and Ying, [43] found that 1-MCP treatment delayed the activities of both cellulose and pectinase in cherry tomato but the effect on cellulose appeared to be more pronounced. PG activity was reported to be suppressed completely in avocado after 1-MCP treatments [44]. Studies have shown that the activity of β-galactosidase and pectin methyl esterase can be greatly suppressed when treated with 1-MCP [45].

For the 1-MCP treated fruit, distinct differences in firmness were observed after 15 d of storage with the treated samples being more firm than the untreated (Table 5). 1-MCP has been known to bind irreversibly to ethylene receptors and

Variables		Storage period (d)					
		15	30	45	60	75	90
1-MCP	0 (control)	3.12±0.02	-	-	-	-	-
	1000	3.02±0.01	3.19±0.02	3.39±0.03	4.50±0.02	-	-
	3000	2.98±0.05	3.03±0.01	3.34±0.01	4.14±0.06	2.24±0.04	4.37±0.04
	5000	2.56±0.05	2.37±0.01	2.42±0.02	2.54±0.07	2.75±0.01	2.93±0.01
LSD(p≤0.05)		0.01	0.01	0.01	0.01	0.01	0.01
ST	11	2.71±0.04	2.72±0.02	3.79±0.05	3.67±0.01	3.85±0.02	4.05±0.01
	13	3.10±0.01	3.14±0.01	2.89±0.03	-	-	-
	15	3.12±0.00	3.33±0.01	-	-	-	-
	29	3.13±0.02	-	-	-	-	-
LSD (p≤0.05)		0.00	0.01	0.01	*	*	*
PB	packaged	3.00±0.03	3.05±0.01	3.18±0.02	3.10±0.04	3.26±0.01	3.71±0.06
	Unpackaged	3.03±0.01	3.09±0.02	2.87±0.02	-	-	-
LSD(p≤0.05)		0.00	0.00	0.01	*	*	*
Cultivars	Broken	3.00±0.00	3.06±0.01	2.88±0.04	4.44±0.02	2.34±0.02	-
	Dausha	3.01±0.02	3.07±0.03	3.60±0.02	3.69±0.04	4.06±0.06	4.17±0.01
LSD (p≤0.05)		0.00	0.00	0.01	0.01	0.02	*
	SE	0.01	0.01	0.90	0.02	0.15	0.03
	CV (%)	0.40	0.60	0.10	2.00	0.23	1.02
Interaction							
p.1-MCP×ST		S	S	S	S	S	S
p.1-MCP×PB		S	S	S	S	S	S
p.1-MCP×Cultivar		S	S	S	S	S	S

Table 6: Total carotenoid (mg/100g) of broken and Dausha mango as affected by 1-MCP concentration (ppb), storage temperature (°C), packaging and cultivar during storage period of 90 d

1-MCP, 1-Methylcyclopropene concentration in ppb; ST, storage temperature in °C; PB, paperboard packaging; LSD, least significant difference at 5% level; - no value; *Values not compare with any at this level. Values are presented as Means±Standard deviations (n=6); S, significant at $p<0.05$ level

ripening of fruit is delayed until new binding sites are synthesized [46]. Before new binding sites are formed due to depletion of 1-MCP, the firmness of the fruit remain preserved. There was no significant difference for fruit firmness at the three levels of 1-MCP concentrations (1000, 3000 and 5000 ppb). This indicates that 1-MCP could be effective at the various concentrations for shelf life elongation of the mango cultivars studied, similar trends of result have earlier been reported [28, 33]. Interestingly, at 5000 ppb 1-MCP concentration, some packaged Dausha fruit samples remained green and firm without being ripened at 90 d while the other fruit treated with lower concentrations spoilt at or before 90 d. The result indicates that Dausha variety has

ISSN No:-2456-2165

potential to store beyond 90 d at 5000 ppb or higher concentrations.

The effect of 1-MCP treatment on fruit firmness significantly ($p<0.05$) varied with storage temperature and time. As shown in Table 5, the firmness of the fruit stored at 11 ^oC was significantly ($p<0.05$) maintained up to day 90. However, at 29 ^oC of storage, firmness decreased more drastically at day 15, and further more rapidly to 90 d. The steady decrease in fruit firmness during storage is a natural phenomenon for almost all climacteric fruit which is as a result of biochemical changes of the cellular structures during ripening. Similar trends have been reported by other researchers [47]. Ripened *Langra* and *Samar Bashisht Chaunsa* Mango showed significant higher firmness when stored at 20 ^oC when compare with higher storage temperature of 30 and 40 ^oC [48]. Higher storage temperatures induce more activity of ripening and softening enzymes thereby reducing firmness.

The packaging material exhibited a significant difference ($p<0.05$) on the firmness of the mango samples throughout the storage periods (Table 5). Packaged fruit required more force to penetrate showing that they were firmer than the unpackaged ones. For instance, 1.99 N was required to penetrate packaged fruit on day 15 while 0.76 N was needed to penetrate the unpackaged fruit stored under the same conditions. The effect of packaging in delaying loss of firmness could be due to MAP created within the packaging free space which may have shown influence to reduce rate of respiration and other metabolic activities in fruit [49]. Similar findings have also been reported on mangoes [30, 50].

In all the storage periods, significant differences ($p<0.05$) were observed with regard to firmness between the two cultivars. Dausha was firmer than Broken (Table 5). The observed variations of firmness among cultivars may be due to genetic differences. This may also be associated with variation in physiological and physical characteristic among the cultivars. With thick skin, the force needed for penetration of the penetrometer is more. Also, with thick skin, a barrier is formed and this barrier reduces the rate of diffusion or amount of 1-MCP reaching the ethylene binding sites. This may also be as a result of differences in tissue density among cultivars [51].

The interaction effect between 1-MCP concentration and storage temperature, 1-MCP concentration and packaging material, 1-MCP concentration and cultivar on the firmness of the mango samples was significantly different ($p<0.05$) throughout the storage period (Table 5).

Variables		Storage period (d)					
		15	30	45	60	75	90
1-MCP	0 (control)	24.28±0.01	-	-	-	-	-
	1000	34.29±0.02	31.31±0.01	28.61±0.03	31.40±0.01	-	-
	3000	44.83±0.04	43.77±0.06	40.95±0.01	37.80±0.02	34.16±0.02	27.21±0.02
	5000	46.75±0.01	45.46±0.04	45.89±0.03	32.28±0.01	40.83±0.00	37.01±0.01
LSD($p\leq0.05$)		0.02	0.01	0.01	0.01	0.02	0.02
ST	11	45.57±0.04	45.21±0.02	43.76±0.02	42.56±0.01	38.91±0.05	38.32±0.01
	13	40.09±0.03	30.04±0.01	24.26±0.01	-	-	-
	15	32.28±0.05	28.19±0.02	-	-	-	-
	29	25.31±0.01	-	-	-	-	-
LSD($p\leq0.05$)		0.02	0.01	0.01	*	*	*
PB	packaged	45.52±0.00	44.61±0.02	45.05±0.02	42.09±0.01	41.06±0.03	39.09±0.01
	Unpackaged	38.56±0.04	30.08±0.03	26.44±0.04	-	-	-
LSD($p\leq0.05$)		0.01	0.01	0.01	*	*	*
Cultivar	Broken	40.77±0.02	39.41±0.01	38.81±0.01	35.67±0.01	23.61±0.02	-
	Dausha	46.06±0.01	45.67±0.03	45.09±0.03	44.98±0.03	39.38±0.05	39.87±0.02
LSD ($p\leq0.05$)		0.01	0.01	0.01	0.01	0.02	*
	SE	0.05	0.19	0.05	0.09	0.03	0.01
	CV (%)	0.20	0.61	0.02	0.01	0.04	0.02
Interaction							
p.1-MCP×ST		S	S	S	S	S	S
p.1-MCP×PB		S	S	S	S	S	S
p.1-MCP×Cultivar		S	S	S	S	S	S

Table 7: Vitamin C content (mg/100g) of Broken and Dausha mango as affected by 1-MCP concentration (ppb), storage temperature (^oC), packaging and cultivar during storage period of 90 d

1-MCP, 1-Methylcyclopropene concentration in ppb; ST, storage temperature in ^oC; PB, paperboard packaging; LSD, least significant difference at 5% level; - no value; *Values not compare with any at this level. Values are presented as Means±Standard deviations (n=6); S, significant at $p<0.05$ level

ISSN No:-2456-2165

D. Total Carotenoids

Statistically significant differences ($p<0.05$) were found regarding the effects of 1-MCP concentration, storage temperature, packaging and cultivar on total carotenoids content of mango fruit (Table 6). The significant increase in carotenoids from the initial values for the control and treated samples during storage was due to onset and progressive ripening. The 1-MCP treated fruit recorded lower increases in carotenoids values compared to the control. Higher amount of carotenoids in the control was because the control fruit were fully ripened and reached early climacteric stage on day 15. The higher total carotenoid content exhibited by the control shows that 1-MCP treatment had significant effect on carotenoid.

The results of this study agree with Mostolji *et al.,* [52] who also reported low carotenoids in tomato fruit using 1-MCP. The lowest carotenoids values recorded for 5000 ppb concentration shows that 1-MCP inhibits respiration, ripening and senescence processes in the stored fruit. Also, 1-MCP with low storage temperature interaction inhibits enzymatic activities that lead to biosynthesis of anthocyanin thereby slowing down ripening process [53].

Generally, there was a gradual increase in the level of carotenoids with storage time irrespective of treatments. These findings are in line with that of [54] who found a sharp increase in carotenoids during ripening.

There was a significant difference ($p<0.05$) between the packaging material and the change in total carotenoid of the two mango cultivars (Table 6). The paperboard packaged fruit maintained lower carotenoids levels throughout the storage period while the unpackaged showed high levels. Carotenoid levels reached their peak on day 60 and thereafter decreased till day 90. Dausha recorded higher level of carotenoids compared to Broken probably due to cultivar differences. The low carotenoids recorded in the packaged fruits could be as a result of the controlled atmosphere in the packs which reduced availability of oxygen required for metabolic enzymes that give rise to respiration, ripening and senescence. The results of this study is in line with Chilungo *et al.,* [55] who attributed the high loss of carotenoids in stored orange-fleshed sweet potato flours to its degradation by oxygen. He submitted that sealing of flour in kraft paper led to high oxygen transmission into the package causing carotenoid oxidation, and hence the losses. He however, attributed low loss of carotenoid recorded in flour packaged in aluminium foil laminate (AFL) to the opaque nature of the AFL as well as the vacuum sealing, which might have prevented carotenoid degradation through photoisomerization and oxidation.

The interaction effect between 1-MCP concentration and storage temperature, 1-MCP concentration and packaging material, 1-MCP concentration and cultivar recorded a significant effect ($p<0.05$) on the total carotenoids of both Broken and Dausha fruit throughout the storage period, indicating the dependency of these variables on each other (Table 6).

Variables		Storage period (d)					
		15	30	45	60	75	90
1-MCP	0 (control)	6.03±0.02	-	-	-	-	-
	1000	5.08±0.03	5.10±0.02	5.47±0.02	7.40±0.02	-	-
	3000	4.30±0.04	4.57±0.01	5.19±0.04	6.20±0.01	6.76±0.03	7.35±0.02
	5000	4.18±0.05	4.27±0.03	4.38±0.03	5.01±0.00	5.25±0.02	7.02±0.00
LSD ($p\leq0.05$)		0.09	0.01	0.01	0.09	0.02	0.04
ST	11	4.26±0.01	4.35±0.02	5.08±0.02	5.10±0.05	5.22±0.01	6.04±0.07
	13	5.19±0.02	5.06±0.03	4.63±0.04	-	-	-
	15	6.14±0.00	7.12±0.01	-	-	-	-
	29	6.70±0.01	-	-	-	-	-
LSD ($p\leq0.05$)		0.09	0.01	0.01	0.01	0.02	0.01
PB	Packaged	4.30±0.04	4.94±0.01	4.11±0.00	5.16±0.01	5.65±5.65	5.95±0.04
	Unpackaged	6.04±0.02	7.02±0.04	7.28±0.01	-	-	-
LSD ($p\leq0.05$)		0.06	0.00	0.01	*	*	*
Cultivar	Broken	5.75±0.04	5.09±0.03	6.31±0.02	7.26±0.02	7.46±0.01	-
	Dausha	4.68±0.05	4.87±0.02	5.09±0.01	5.04±0.01	5.36±0.03	5.62±0.01
LSD ($p\leq0.05$)		0.06	0.00	0.01	0.07	0.02	*
	SE	0.22	0.06	0.01	0.08	0.04	0.41
	CV (%)	4.00	5.41	0.45	7.00	3.12	3.13
Interaction							
p.1-MCP×ST		NS	S	S	S	S	S
p.1-MCP×PB		NS	S	S	S	S	S
p.1-MCP×Cultivar		NS	S	S	S	S	S

Table 8: The pH of Broken and Dausha mango as affected by 1-MCP concentration (ppb), storage temperature (°C), packaging and cultivar during storage period of 90 d

1-MCP, 1-Methylcyclopropene concentration in ppb; ST, storage temperature in °C; PB, paperboard packaging; LSD, least significant difference at 5% level; - no value; *Values not compare with any at this level. Values are presented as Means±Standard deviations (n=6); NS, nonsignificant at $p>0.05$ level; S, significant at $p<0.05$ level

ISSN No:-2456-2165

E. Vitamin C

Significant differences ($p<0.05$) were observed between treatments and vitamin C throughout the storage period (Table 7). There was an increase in vitamin C content from day zero to day 15 with a gradual decrease from day 45 to 90. The control showed faster decrease in vitamin C than the fruit treated with 1-MCP. Among the treatments, fruit treated with 5000 ppb 1-MCP recorded significantly higher value of vitamin C followed by fruit treated with 3000 ppb 1-MCP on day 15. A decreasing trend was observed from day 30 of storage up to the end. The results obtained from this study indicate that 1-MCP treatments were significant in retarding the degradation of vitamin C content of mango fruit during storage. Decrease in vitamin C during storage has been reported in studies on vegetables such as, *capsicum* [56], banana [57], tomatoes [58] and in mango fruit [30, 59]. The decrease in vitamin C content of mango fruit during storage may be attributed to the biochemical processes that fruit undergo before and after harvest.

There was a significant effect ($p<0.05$) between storage temperature and vitamin C content (Table 7). The changes in vitamin C showed dependence on temperature, with vitamin C content decreasing as the temperature increased. For example, the vitamin C content recorded on day 15 was 45.52 mg/100g and 25.31 mg/100g at 11 ^{o}C and 29 ^{o}C (ambient) respectively and decreases with storage time. The higher vitamin C losses at 29 ^{o}C than 11 ^{o}C may be due to the instability of vitamin C at higher temperatures, being heat labile. This result is in line with other studies in which increased temperature and storage time were associated with increased vitamin C losses [60, 61]. These finding show that the combination of 1-MCP treatment and low temperature storage will retain more vitamin C during storage. Similar results have been reported where juice stored at 10 ^{o}C with preservatives retained more vitamin C than that stored at 29 ^{o}C (ambient) temperatures [62].

The PB packaging also recorded significant effect ($p<0.05$) on the vitamin C content of mango fruit throughout the storage time (Table 7). On the first 15 d of storage, PB packaged fruit recorded 45.52 mg/100g of vitamin C while unpackaged fruit recorded 38.56 mg/100g. The unpackaged recorded lower vitamin C content because it was exposed to free oxygen in the atmosphere and can oxidize readily in the presence of oxygen by both enzymatic and nonenzymatic catalyst [63]. Irrespective of packaging; the vitamin C content of the fruit decreased significantly ($p<0.05$) with increased storage period. Vitamin C losses were lower in fruit stored in PB packaging than unpackaged. Similar trend was observed by other researchers where mango juice was packaged in polyethylene films, polyethylene tetraphthalate (PET or Plastic) bottles and transparent glass bottles and stored at different temperatures (6 ^{o}C, 26 ^{o}C and 34 ^{o}C) [64].

There was significant difference ($p<0.05$) between Vitamin C content and cultivars during storage (Table 7). Broken showed slightly higher losses in vitamin C content than Dausha throughout the storage period. The difference in vitamin C exhibited by cultivars could be as a result of maturity, variety, genetic and physiological composition. The vitamin C values recorded for various treatments were sufficient at day 60 to meet the 45 mg recommended daily allowance (RDA) for adults [65], the values above 60 d of storage were lower than the RDA.

The interaction effect of 1-MCP concentration and storage temperature, 1-MCP concentration and packaging, and 1-MCP concentration and cultivar on the changes in vitamin C content were significant ($p<0.05$) (Table7)

F. pH

At the initial stage, the pH of all the mango samples was in acidic medium. However, at 15 d of storage, the pH of untreated samples moved faster towards alkalinity while that of treated samples moved with a smaller margin towards alkalinity but were still within the acidic range (Table 8). At day 60 of storage, the 1000 ppb treated samples of Broken attained pH in alkalinity region while Dausha remained in acidic range, increasing marginally to 5.62 at 90 d of storage. In general, the 1-MCP treated fruit maintained their pH in acidic region and with increased concentration of 1-MCP throughout the storage time. The highest pH values were recorded by the control while the lowest was by the 5000 ppb 1-MCP treated samples.The pH differed significantly ($p<0.05$) on days 30, 45, 75 and 90 irrespective of treatments (Table 8). Lower pH value indicates more acidic fruit and the minimum changes in pH may be due to a slower rate of respiration and metabolic activities in 1-MCP treated samples [66]. The general retention in pH of treated samples might also be due to the inhibition of organic acids biosynthesis and ripening by 1-MCP. The 5000 ppb 1-MCP treated samples significantly ($p<0.05$) showed lower pH values compared to 1000 and 3000 ppb 1-MCP.

Storage temperature had significant ($p<0.05$) effect on the pH of mango fruit except on day 15 (Table 8). The pH increases significantly ($p<0.05$) as the storage temperature increased at various storage days throughout the storage time. Lowest pH values were recorded at 11 ^{o}C and higher values at 15 ^{o}C and ambient (29 ^{o}C). Higher temperatures favour biosynthesis of organic acids in the fruit resulting in higher pH values [67].

ISSN No:-2456-2165

Variables		Storage period (d)					
		15	30	45	60	75	90
1-MCP	0 (control)	0.66±0.03	-	-	-	-	-
	1000	0.81±0.02	0.60±0.02	0.51±0.02	0.41±0.02	-	
	3000	1.36±0.00	1.31±0.02	1.25±0.04	1.08±0.01	0.92±0.2	0.76±0.03
	5000	1.44±0.01	1.38±0.03	1.32±0.01	1.28±0.02	1.22±0.04	1.17±0.02
LSD (p≤0.05)		0.01	0.04	0.01	0.02	0.02	0.03
ST	11	1.43±0.02	1.40±0.02	1.15±0.01	1.42±0.05	1.31±0.07	1.20±0.01
	13	1.06±0.03	0.81±0.01	0.35±0.03	-	-	-
	15	0.95±0.02	0.70±0.04	-	-	-	-
	29	0.89±0.02	-	-	-	-	-
LSD (p≤0.05)		0.01	0.04	0.01	*	*	*
PB	packaged	1.39±0.04	1.37±0.02	1.34±0.03	1.32±0.01	0.98±0.01	1.10±0.05
	Unpackaged	0.78±0.02	0.72±0.01	0.34±0.02	-	-	-
LSD (p≤0.05)		0.01	0.04	0.01	*	*	*
Cultivars	Broken	1.06±0.00	1.01±0.02	0.96±0.04	0.93±0.02	0.60±0.04	-
	Dausha	1.45±0.10	1.28±0.04	1.26±0.01	1.23±0.01	1.06±0.02	0.97±0.01
LSD (p≤0.05)		0.00	0.04	0.01	0.01	0.02	*
SE		0.01	0.35	1.23	0.06	0.32	0.04
CV (%)		1.40	0.03	8.00	0.02	0.01	1.02
Interaction							
p.1-MCP×ST		S	S	S	S	S	S
p.1-MCP×PB		S	S	S	S	S	S
p.1-MCP×Cultivar		S	S	S	S	S	S

Table 9: Titratable acidity (%) of Broken and Dausha mango as affected by 1-MCP concentration (ppb), storage temperature (°C), packaging and cultivar during storage period of 90 d

1-MCP, 1-Methylcyclopropene concentration in ppb; ST, storage temperature in °C; PB, paperboard packaging; LSD, least significant difference at 5 % level; - no value, *Values not compare with any at this level. Values are presented as Means±Standard deviations (n=6); S, significant at p<0.05 level

There was a significant (p<0.05) variation between the pH of packaged and unpackaged mango fruit throughout the storage period except on day 15 (Table 8). Packaged fruit recorded lower pH values than unpackaged fruit. The lower pH values recorded in packaged fruit may be due to high humidity in the packs which delayed ripening and resulted in slow hydrolysis of organic acids [68].

There was also significant difference (p<0.05) in pH among cultivars throughout the storage time except on day 15 (Table 8). In each storage period, pH was found to be higher in Broken compared to Dausha. The variation in pH might be due to differences in maturity stage and genetic dissimilarities among the two cultivars [69]. This study, therefore, showed that treatment of mango fruit with 1-MCP has significant effect on pH and their effectiveness is concentration dependent. The pH of mango fruit is determined primarily by the acid content of the fruit. The result is in agreement with the findings of other researchers [70, 71].

There was a significant interaction effect (p<0.05) between 1-MCP concentration and storage temperature, 1-MCP concentration and packaging material, 1-MCP concentration and cultivar on pH of the mango samples throughout the storage period except day 15 (Table 8).

G. Titratable Acidity

The titratable acidity (TTA) of the mango fruit was significantly affected (p<0.05) by 1-MCP concentration, paperboard packaging, storage temperature and cultivars throughout the storage period (Table 9). Mango fruit subjected to 1-MCP treatment showed significantly higher TTA content compared to those untreated throughout the storage periods. Irrespective of experimental conditions, TTA was found to decrease during storage due to ripening of fruit at all storage conditions. On the initial day, the TTA of the mature green fruit was 1.43 and 1.46 % for Broken and Dausha respectively and at 75 d; it decreased to about 0.60 and 1.06 %. The decrease in TTA across the storage period may be due to a decrease in the concentration of organic acid as ripening progresses. There was also conversion of citric acids into sugars which were further utilized in other metabolic process of the fruits [67, 72]. The sugars may have been consumed

ISSN No:-2456-2165

during transpiration and respiratory processes [73]. Also, 1-MCP may have possibly delayed the metabolism of carbohydrate [74]. The above mentioned behaviour of the mango cultivars studied is in line with that found in tomato [75] and strawberry [76]. This result is in line with other studies on Guava [77], Pineapple [78] and Plum fruit [79].

The paperboard packaging significantly affected ($p<0.05$) the changes in TTA of mango fruits during the storage periods. Packaged fruits exhibited higher TTA compared to the unpackaged fruit (Table 9). The higher TTA associated with packaged fruit may be due to low availability of oxygen in the storage environment for organic acids biosynthesis. This might also be because of slow rate of ethylene production by the packaged mangoes [80]. Generally, TTA was high at the early stage of storage than the late stage, showing that unripe fruit are more acidic than ripe fruit and that ripening reduces the acid content in fruit. The findings in this study are in line with those earlier reported [28, 30].

	Storage period (d)					
Variables	15	30	45	60	75	90
1-MCP 0 (control)	22.04±0.01	-	-	-	-	-
1000	20.66±0.02	21.94±0.01	21.87±0.00	22.00±0.01	-	-
3000	19.83±0.02	20.48±0.04	19.10±0.03	20.26±0.03	19.71±0.02	19.86±0.04
5000	18.07±0.03	18.25±0.01	17.35±0.00	19.18±0.01	19.13±0.05	18.16±0.01
LSD($p\leq0.05$)	0.07	0.02	0.01	0.02	0.01	0.03
ST 11	18.16±0.03	18.66±0.01	18.12±0.02	19.08±0.06	18.36±0.01	18.46±0.02
13	19.97±0.01	20.85±0.03	16.03±0.05	-	-	-
15	20.33±0.02	21.25±0.01	-	-	-	-
29	22.14±0.00	-	-	-	-	-
LSD ($p\leq0.05$)	0.07	0.45	0.01	*	*	*
PB packaged	18.18±0.02	18.51±0.04	18.62±0.02	19.23±0.01	18.46±0.07	18.22±0.01
Unpackaged	20.63±0.00	20.66±0.01	22.53±0.01	-	-	-
LSD ($p\leq0.05$)	0.05	0.37	0.01	*	*	*
Cultivars.Broken	20.68±0.02	21.04±0.01	19.68±0.02	20.74±0.02	18.06±0.03	-
Dausha	18.13±0.04	18.14±0.02	19.47±0.05	20.55±0.01	19.58±0.01	19.54±0.06
LSD ($p\leq0.05$)	0.05	0.05	0.01	0.01	0.01	*
SE	0.17	0.21	0.14	1.07	0.09	1.04
CV (%)	0.80	0.90	0.60	5.12	0.34	0.07
Interaction						
p.1-MCP×ST	NS	NS	S	S	S	S
p.1-MCP×PB	NS	NS	S	S	S	S
p.1-MCP×Cultivar	S	S	S	S	S	S

Table 10: Total soluble solids (%) of Broken and Dausha mango as affected by 1-MCP concentration (ppb), storage temperature (^oC), packaging and cultivar during storage period of 90 d

1-MCP, 1-Methylcyclopropene concentration in ppb; ST, storage temperature in ^oC; PB, paperboard packaging; LSD, least significant difference at 5% level; - no value; *Values not compare with any at this level. Values are presented as Means±Standard deviations (n=6); NS, nonsignificant at $p>0.05$ level; S, significant at $p<0.05$ level

ISSN No:-2456-2165

Variables		Storage period (d) 15	30	45	60	75	90
1-MCP	0 (control)	33.40±0.02	-	-	-	-	-
	1000	25.51±0.00	33.57±0.02	34.72±0.04	34.96±0.01	-	-
	3000	19.44±0.03	32.15±0.03	33.25±0.03	33.51±0.03	28.08±0.03	17.44±0.02
	5000	17.34±0.00	19.37±0.02	21.55±0.01	21.63±0.02	19.41±0.01	18.03±0.01
LSD (p≤0.05)		0.07	0.02	0.02	0.01	0.01	0.01
ST	11	16.08±0.02	17.58±0.01	21.32±0.04	21.58±0.02	20.22±0.10	19.10±0.01
	13	20.22±0.02	21.74±0.02	22.80±0.03	-	-	-
	15	21.40±0.03	22.36±0.01	-	-	-	-
	29	25.78±0.07	-	-	-	-	-
LSD (p≤0.05)		0.10	0.03	0.03	*	*	*
PB	packaged	17.38±0.10	18.01±0.01	19.68±0.02	20.34±0.10	20.13±0.03	18.56±0.01
	Unpackaged	19.45±0.01	20.69±0.04	24.37±0.01	-	-	-
LSD (p≤0.05)		0.30	0.02	0.05	*	*	*
Cultivars.	Broken	18.22±0.04	20.68±0.01	21.67±0.01	22.85±0.02	24.60±0.02	-
	Dausha	17.19±0.03	19.15±0.02	19.47±0.01	19.95±0.01	19.24±0.04	18.67±0.03
LSD (p≤0.05)		0.10	0.03	0.05	0.01	0.01	*
SE		0.47	0.08	0.14	0.09	0.02	0.36
CV (%)		10.16	0.01	0.45	0.23	0.12	0.33
Interaction							
p.1-MCP×ST		NS	S	S	S	S	S
p.1-MCP×PB		NS	S	S	S	S	S
p.l-MCP×Cultivar		NS	S	S	S	S	S

Table 11: Total soluble solids/titratable acidity ratio of Broken and Dausha mango as affected by 1-MCP concentration (ppb), storage temperature (°C), packaging and cultivar during storage period of 90 d

1-MCP, 1-Methylcyclopropene concentration in ppb; ST, storage temperature in °C; PB, paperboard packaging; LSD, least significant difference at 5% level; - no value; *Values not compare with any at this level. Values are presented as Means±Standard deviations (n=6); NS, nonsignificant at p>0.05 level; S, significant at p<0.05 level

There was a significant variation (p<0.05) between the storage temperature and TTA throughout the storage period. The TTA decreases with storage temperature and time and is highly temperature dependent. The TTA values for day 15 at 11 °C was 1.43 % and at 29 °C (ambient) 0.89 %. The TTA of the fruit stored at 29 °C (ambient) was lower than samples stored at 11, 13 and 15 °C. During storage, the fruit kept at room temperature (29 °C) recorded TTA similar to that of the control (Table 9). At high temperatures, the mango fruit ripened in a relatively short storage time resulting to decrease in acidity thereby reducing the desired quality of fruit [81]. It was also observed from the result of the study that TTA is inversely proportional to the TSS content of the fruit.

Highly significant variation (p<0.05) was observed in the TTA and cultivars throughout the storage period (Table 9). Dausha exhibited higher TTA values compared to Broken at various days of storage. The TTA values of Dausha and Broken on day 15 were 1.45 and 1.06 % respectively. The difference in TTA of the two mango cultivars might be due to genetic and physiological composition.

The interaction term, 1-MCP concentration and storage temperature, 1-MCP concentration and packaging, 1-MCP concentration and cultivar significantly (p<0.05) contributed to changes in the TTA of the mango fruit throughout the storage period.

H. Total Soluble Solids

Regardless of storage period control fruit exhibited higher total soluble solids content (TSS) compared to the 1-MCP treated. There was a tremendous increase in TSS content in control (22.04 **%**) samples for the first 15 days of storage. The 1-MCP treated fruit recorded relatively slow increase rates in TSS for the first 30 d which gradually reached peak values on day 60, and decreased thereafter till the end of the storage period (Table 10). The findings of this study are in line with the findings of Tefera *et al.*, [82] who also reported initial increase in TSS followed by subsequent decrease until a full senescence stage was reached. The low TSS content recorded in the treated samples at the initial stages of the preservation process shows that ripening process was inhibited by 1-MCP. Among the 1-MCP treatments, 3000 and 5000 ppb recorded lower TSS contents with 5000 ppb treatment being the lowest. The observed increment in TSS to peak levels and subsequent decline followed natural fruit ripening and senescence processes seen in related traits like colour change and firmness which are typical of postharvest change in climacteric fruit [83]. This result is in agreement with the findings of Dharmasenal and Kilmari [84] and Salvador *et al.*, [85] who reported increase in TSS of different banana varieties from 0 to 17 % over a storage period of 16 d. The increase in TSS of the mango fruit in this work could be due to the hydrolysis of various structural polysaccharides, such as starch, pectins, and other oligosaccharides in the cell wall. These polysaccharides when solubilized in the aqueous phase become part of the cellular juice [86]. In the same way the starch that has accumulated during fruit maturation is being degraded to

ISSN No:-2456-2165

simple sugars by the enzymatic action of α-amylase, β-amylase and starch phoshorylase thereby increasing the TSS content [48].

There was significant variation ($p<0.05$) in the effect of storage temperature on TSS (Table 10). The TSS content increased with storage temperature throughout the storage time. On day 15 and at 11 ^{o}C, TSS was 18.16 %, at 29 ^{o}C (ambient) it increased to 22.14 %. Higher storage temperatures yielded rapid increase in TSS of the mango fruit. At 29 ^{o}C, the mango fruit exhibited a shorter time for ripening resulting to higher TSS. On the other hand, the mango fruit stored at 11, 13 and 15 ^{o}C ripened more slowly and therefore had low TSS content. A delay in change in TSS content indicates prolongation of the postharvest life of the mango fruit [87].

There was significant difference ($p<0.05$) in the TSS of packaged and unpackaged mango fruit during the storage period (Table 10). Mango fruit packaged in paper board maintained low TSS (18.18 to 19.23 %) throughout the storage period. Unpackaged fruit on the other hand had higher TSS (20.63 to 22.53 %). This clearly shows that packaging delays ripening process. The unpackaged fruit attained the highest TSS level on day 45 while paperboard packaged fruit reached maximum TSS level (19.23 %) on day 60. This result showed that PB packages delayed ripening period of mango fruit for more than 60 d. This similar trend was observed by Alye [31].

The difference in TSS between PB packaged and unpackaged could be as a result of modified atmosphere created by the packaging system and the binding of 1-MCP with ethylene receptor. The delay in ripening of the fruit may be due to slow hydrolysis of starch, pectic acid, proteins and fats resulting to low TSS. The decrease in TSS after 60 d of storage may be due to further utilization of sugars during respiration and degradation of total soluble substances because of prolonged storage. Zagory and Kedar [49] and Golding *et al.,* [88] both reported similar trends. On the other hand the observed increment in TSS content of unpackaged fruit may be due to high respiration rate and ripening thereby resulting in quality deterioration with the onset of senescence]89].

There was significant difference ($p<0.05$) in TSS of the mango fruit varieties (Table 10). Broken exhibited higher TSS throughout the storage period while Dausha showed lower TSS. The differences in TSS among mango varieties might be due to genetic and physiological characteristics. It has also been reported that the ability of 1-MCP to inhibit ethylene production varies with cultivar [29].

The interaction effect showed no significant difference ($p>0.05$) between 1-MCP concentration and storage temperature, 1-MCP concentration and packaging on day 15 and 45 but significantly different ($p<0.05$) on day 45 to 90 while the interaction effect between 1-MCP concentration and cultivar on total soluble solids of mango fruit showed significant difference ($p<0.05$) throughout the storage period (Table 10).

I. TSS/TTA Ratio

The delay in the degradation of starch and organic acids by 1-MCP has given rise to significantly lower TSS/TTA ratio in 1-MCP treated fruit when compared with the control (Table 11). Whereas at day 15, the control had high TSS/TTA ratio of 33.40, that of 5000 ppb 1-MCP treated samples was low, being 12.55. The TSS/TTA ratio for day 15 of treated samples was nonsignificant ($p>0.05$) but significantly different ($p<0.05$) from day 30 to 90 of the storage time. This may be due to the metabolism of sugars and organic acids as the effect of 1-MCP tends to depreciate. The results obtained in the present work for TSS/TTA ratio is higher than 10.81 reported for the control, 9.90 to 10.44 for the 1-MCP treated on day 15, 10.52 to 11.72 and 9.61 to 11.85 reported for 1-MCP treated on day 30 and 45 respectively by Rosa *et al*., [90]. However, the findings in the study are lower than those reported by Zucoloto *et al*., [91]. The differences in the values could be as a result of treatments, variety, climate and time of harvesting. It has earlier been reported that the TSS/TTA ratio is often better related to palatability of the fruit than either TSS or TTA levels alone [34]. The ratio is considered as a key characteristic determining the taste, texture and feel of fruit segments. It is also an indicator of commercial and sensory ripeness. Therefore, fruit with high TSS/TTA ratio are rated high in quality while those with low TSS/TTA rated low in quality [70]. However, the low TSS/TTA ratio recorded at the initial stage in treated fruit does not mean that they have inferior eating qualities but because they have not reach their ripening stage due to 1-MCP treatments.

The results showed significant interaction ($p<0.05$) between 1-MCP concentration and cultivar, 1-MCP concentration and packaging, and 1-MCP concentration and storage temperature for TSS/TTA ratio throughout the storage period indicating that the ratio is concentration-dependent.

IV. CONCLUSION

The 1-MCP concentration, packaging material, storage temperature and time exhibited significant effect ($p<0.05$) on the postharvest quality of the two mango cultivars, Broken and Dausha. The 1-MCP treated and packaged fruit stored at refrigerated temperatures showed the least decay/chilling injury, better colour retention and firmness. It maintained total carotenoids, vitamin C, titratable acidity, low pH values and TSS/TTA ratio for the two cultivars investigated. The results showed that 1-MCP application could be used in maintaining the postharvest quality of mango fruit. Further investigation may be needed to evaluate other forms of application of 1-MCP (liquid or spray) and packaging materials on mango cultivars and other food crops grown in Nigeria.

ACKNOWLEDGMENT

The authors acknowledge, with deep appreciation, the kind donation of 1-methylcyclopropene by Eurofins Agroscience Services, San Giorgio Din Piano, Bologna, Italy and the Department of Chemistry, Benue State University, Makurdi, Nigeria, for using the laboratory equipment and facilities.

REFERENCES

[1.] Sharma, S. (2015). Food preservatives and their harmful effects, International Journal of Scientific Research and Publications, 5(4): 2150
[2.] Sofos, J. N., Pierson, M. D., Blocher, J. C. and Busta, F. F. (1986). Mode of action of sorbic acid on bacterial cells and spores, International Journal of Food Microbiology, 3:1-6
[3.] Talcott, S. T., Moore, J. P., Lounds-Singleton, A. J. and Percival, S. S. (2005). Ripening associated phytochemical changes in mangoes (Mangifera indica) following thermal quarantine and low-temperature storage, Journal of Food Science, 70:337-341
[4.] Blankenship, S. M. and Dole, J. M. (2003). 1-MCP: A Review, Postharvest Biology. Technology, 28:1-3
[5.] Jean, P. B. (1994). Food Preservation, Nicolas Appertinventeur at humaniste, http://www.appert_aina.com. Retrieved 08/10/2015
[6.] Daniel, M. (2007). Reactions to Food Additives and Preservatives, https://www.foodalllergy.org. Retrieved 24th /7/2016
[7.] Heldman, E. R. (1994). Frozen foods challenges for the future, Food Australia, 45(8): 374-380
[8.] Saulo, A. A. (1994). Sugars and sweeteners in foods, food safety and technology, published by College of Tropical Agriculture and Human Resources, University of Hawai'l at manoa, FST-16
[9.] Benhura, C., Rukuni, T., Kadema, C., Mubvakure, B., Nazare, R., Gombiro, P. E., Tokwe, B., Matangi, E. and Madzima, A. (2012). Preservation of mango pulp of fruit from Rusitu Valley, Chimanimani in Zimbabwe, Pakistan Journal of Food Sciences, 22(4): 191-192
[10.] Msagati, T. A. M. (2012). The chemistry of food additives and preservatives. http://www.eblib.com, Retrieved 08/02/2016
[11.] Younis, S. M., Butt, S.M., Sharif, K. M., Sulerai, R. A. H. and Hameed, F. (2011). Effects of preservatives on the physicochemical, microbial and sensory attributes of mangoes, Internet Journal of Food Safety, 13:246-254
[12.] Caicedo, V., Susanne, A. S., Reinhold, C., and Sybille, N. (2007). Effects of thermal processing and fruit matrix on b-carotene stability and enzyme inactivation during transformation of mangoes into puree and nectar, Food chemistry, 102:1172 – 1186
[13.] Chiriboga, M. A., Schotsmans, W. C., Larrigaudiere, C., Dupille, E. and Recasens, I. (2011). How to prevent ripening blockage in 1-MCP treated 'Conference' pears, Journal of Science and Food Agriculture, 91:1781-1788
[14.] Watkins, C. B. (2008b). Postharvest effects on the quality of horticultural products: using 1-MCP to understand the effects of ethylene on ripening and senescence processes, Acta Horticulture, 768:19-32
[15.] Watkins, C. B. (2010). 1-methylcyclopropene (1-MCP), Department of Holticulture University Ithaca, NY. P.7. Retrieved from: https://www.researchgate.net/profile/HoudaKawas/post/why ethylene inhibited sprouting of potatoes while not for the 1-MCP which was different in onion/attachment/59d636679197b807799a340/AS:419542112194571@1477038042819/download/1-MCP.pdf
[16.] US-Environmental Protection Agency (2002). EPA Federal Register 67: 48796-48800
[17.] Mamiro, P., Fweja, L., Chove, B., Kinabo, J., George, V. and Mtebe, K. (2007). Physical and chemical characteristics of off-vine ripened Mango (Mangifera indica L.) fruit (Dodo), African Journal of Biotechnology, 6 (21): 2477-2483
[18.] Noiwan, D., Suppakul, P., Joomwong, A., Uthaibutra, J. and Rachtanapu, P. (2017). Kinetics of mango fruits (Mangifera indica cv.'Nam Dok Mai Si Thong') quality changes during storage at various temperatures, Journal of Agricultural Science, 9(6): 199-201
[19.] Dominguez, I., Ferreres, F., del Riquelme, F. P., Font, R. and Gill, M. I. (2012). Influence of preharvest application of fungicides on the postharvest quality of tomato (Solanum lycopersicum L.). Postharvest Biology and Technology, 72: 1-10
[20.] AOAC (1990). Official methods of Analysis, volume I, 16th edition, Association of Official Analytical Chemists, Washington, DC
[21.] AOAC (2000). Official methods of Analysis, volume II, 17th edition. Association of Official Analytical Chemists, Washington, DC
[22.] Nagata, M. and Yamashita, I. (1992). Simple methods of simultaneous determination of chlorophyll and carotenoids in tomato fruit. National Research Institute of Vegetables, Ornamental Plants and Tea, 360: 514-523
[23.] Valenzuela, J. L., Manzano, S., Palma, F., Carvajal, F. and Garrido, D. (2017). Oxidative stress associated with chilling injury in immature fruit postharvest technology and biotechnological solutions. International Journal of molecular Science, 18:1467
[24.] Sisler, E. C. and Serek, M. (2003). ''Compounds interacting with the ethylene receptor in plants'', Plant Biology, 5(5): 473-80. dio: 10.1055/s-2003-44782
[25.] Agrofresh (2005, December 11). 'Draft label for tablets', a publication by Rohm and Hass company Philadelphia, P A
[26.] Zhang, J., Ma, Y., Dong, C., Leon, A. T., Watkins, C. B., Yu, Z. and Cheng, Z. M. (2020). Metal-analysis of the effects of 1-methylcyclopropene (1-MCP) treatment on climacteric fruit ripening, Horticulture Research, 7: 208
[27.] Wang, T. W., Wu, C. and Thompson J. E. (2005). Autisense suppression of deoxyhypusine synthase in tomato delays fruits softening and alters growth and development, Plant physiology 138:1372-1382.
[28.] Silva, S. M., Santos, E. C., Santos, A. F., Silveira, I. R. B. S., Mendonca, R. M. N. and Alves, R. E. (2004). Influence of 1-methylcycloprone on postharvest conservation of exotic mango cultivars, Acta Horticulture, 645: 565 – 572

[29.] Watkins, C. B., Nock, J. F. and Whitaker, B. D. (2000) Responses of early, mid and late season apple cultivars to postharvest application of 1-methylcyclopropene (1-MCP) under air and controlled atmosphere storage conditions,Postharvest Biology and Technology, 19:17-32

[30.] Cocozza, F. M., Jorga, J. T., Alve, R. F., Filigveciras, H. A. C. and Pereira, M. E. C. (2004) Respiration rate and chemical characteristic of cold stored "Tommy Atkins'' mangoes influenced by 1-MCP and modified atmosphere packaging. Proceedings of 7th International mango symposium, Acta Horticulture, 645: 645-50

[31.] Alye, T. (2005). 'Effect of disinfection, packaging and evaporative cooling storage on shelf life of mango (Mangifera indica L), M.Sc Thesis. Alemaga University, Ethiopia

[32.] Hans, P. J., Wittering, E. J. and Peppelenbos, H. N. (1999). Carbon dioxide and 1-MCP inhibit ethylene production and respiration of pear fruit by different mechanisms. Journal of Experimental Botany, 50(335): 837-844

[33.] Delgado-Pelayo, R., Gallardo-Guerrero, I. and Hornero-Mendez, D. (2014). "Chlorophyll and carotenoid pigments in the peel and flesh of commercial apple fruit varieties". Food Research International, 63: 272-281

[34.] Pauziah, M. and Ikwan Reza Mohd Wan, W. H., (2014). Effects of 1- methylcyclopropene on quality of Chokanan mangoes stored at ambient, Journal of Tropical Agriculture and Food Science, 42 (1): 37 – 49

[35.] Diane, M. B., John, C. B. and Rob, S. (2010). Colur, flavour, texture, and nutritional quality of fresh-cut fruits and vegetables: desirable levels, instrumental and sensory measurement and the effects of processing, Critical Reviews in Food Science and Nutrition, 50: 369-389.

[36.] Fabi, J. P., Cordenunsi, B. R., Brreto, G. P. M., Mercadante, P. Z., Lajolo, F. M. and Nascimento, J. R. O. (2007). Papaya fruit ripening: response to ethylene and 1-methylcyclopropene (1-MCP), Journal of Agricultural and Food chemistry, 55:6118-6123

[37.] Moretti, C. L., Marouelli, W. A., Silva, W. L. C., Souza, R. M. and Arouja, A. L (2001). Proc. Fla. Horticultural Society, 114: 145-148

[38.] Hewavitharana, A. K., Tan, Z. W., Shimada, R., Shaw, P. N., Flanagam, B. M. (2013). Between fruit variability of the bioactive compounds, β-carotene and mangiferin in mango (Mangifera indica), Nutrition Diet, 70: 158-163)

[39.] Montalvo, E., Garcia, H. S., Tovar, B. and Mata, M. (2007). Application of exogenous ethylene on postharvest ripening of refrigerated 'Ataulfo' Mangoes, Food Science and Technology, 40 (8): 1466-1472

[40.] Kader, A. and Mitchan, B. (2008). Optimum procedures for ripening mangoes, in fruit ripening and ethylene management, University of California, Postharvest Technology Research and Information Centre publication series 9: 47-48 http://postharvest.ucclavis.edu/pubs/pub-Dec-9. pdf

[41.] Sanudo, J., Siller, J., Osuna, T., Rangel, D. M., Lopez, G. and Laba Vitch, J. (2008). Control de la Maduracion en frutos de papaya (Carica papaya L) con 1-Metilciclopropeno yacido 2- Cloroetil fosfonico. Revista Fitotecnia Mexicana, 31: 141-147.

[42.] Goulao, L. F., Santos, J., Sousa, L. and Oliveira, C. M. (2007). Patterns of enzymatic acitivity of cell wall modifiying enzymes during growth and ripening of apples, Postharvest Biology and Technology, 43: 307-318

[43.] Opiyo, A. M. and Ying, T. (2010). Regulation of cellulose and pectinase activities in cherry tomato (Lycopersicon escucentum Mill Var. Cerasiforme) fruit by use of 1-methylcyclopropene ARPN, Journal of Agricultural Biology Science, 5: 55-64

[44.] Jeong, J., Huber, D. J. and Sargent, S. A. (2002). Influence of 1-Methylcyclopropene (1-MCP) on ripening and cell wall matrix polysaccharides of avocado (Persea americana) fruit. Postharvest Biology and Technology, 25: 241-256

[45.] Razali, M., Zainon, M. A. and Roohaida, O. (2007b). Suppression of softening enzyme activity in papaya (Carica papaya var. Sekaki) by 1-methylcyclopropene during ripening, HRC Technical Report, 125-128

[46.] Matthesis, J. P., Fan, X. and Argenta, T. (2003). Management of climacteric fruit ripening with 1-Methylcyclopropene, an inhibitor of ethylene action: Proceeding of plant growth regulations, Acta Horticulture, 1: 20-25

[47.] Gaikwad, S. S., Sakhale, B. K. and Chavan, R. F. (2020). Effect of 1-MCP concentration, exposure time and storage temperature of postharvest quality of mango fruits C.V Alphanso Food Research, 4(3):746-752 http://www.myfoodresearch.com

[48.] Baloch, M. K. and Bibi, F. (2012). Effect of harvesting and storage conditions on the postharvest quality and shelf life of mango (Mangifera indica L.) fruit, South African Journal of Botany, 83:109-116

[49.] Zagory, D. and Kedar, A. A. (1998). Modified atmosphere packaging of fresh produce, Food Technology, 42 (9): 70-77

[50.] Zeweter, A. (2008). Effect of 1-Methylcyclopropene, potassium permanganate and packaging materials on quhality and shelf life of banana (Musa acuminate Var) (Dwarf Cavendis). M.Sc Thesis. Alemaya University, Ethopia.

[51.] Foukaraki, S. G., Chope, G. A. and Terry, L. A. (2011). 1-MCP application before continuous ethylene storage suppresses sugar accumulation in the Uk-grown potato CV. Marfona. 4th postharvest unlimited, Leavenworth, WA, USA

[52.] Mostolji Y., Toivonen, P. M. A., Lessani, H., Babalar, M. and Lu, C. (2003). Effects of 1-Methylcyclopropene on ripening of greenhouse tomatoes at three storage temperatures, Postharvest Biology and Technology, 27: 285-292

[53.] Sathupaty, S. V. (2012). Effects of postyarvest treatments and packaging materials on shelf life and quality control of tomato (solanum lycopersium L) CV Lakshmi under ambient condition, Horticultural College and Research Institute Venkataramannagudem

[54.] Radzevicius, A., Karkleliene, R., Viskelis, P., Bobinas, C., Bobinaite, R., Sakalauskicre, S. and Metspalu, L. (2012). Tomato (Lycopersicon esculentum Mill.) fruit quality and physiological paramenters at different ripening stages of Lithuanian cultivars, Agronomy Research, 7 (2):712-718.
[55.] Chilungo, S., Muzhingi, T., Truong, V. and Allen, J. C. (2019). Effect of storage and packaging materials on colour and carotenoid content of orange-fleshed sweet potato flours, International Journal of Innovation science and Research Technology, 4(9):362-369
[56.] Rahaman, M. S., Al-rizeigi, M. H. and Guizani, N. (2015). Stability of vitamin C in fresh and freeze-dried capsicum stored at different temperatures. Journal of Food Science and Technology, 52: 1691-1697
[57.] Lec, S. K. and Kader, A. A. (2000). Preharvest and postharvest factors influencing vitamin C content of horticultural crops. Postharvest Biology and Technology, 20: 207-220
[58.] Znidarcic, D., Ban, D., Karic, L. and Oplanic, M. (2010). Influence of postharvest temperature on physico-chemical quality of tomatoes (Lycopersican esculentum mill), Journal of Food Agriculture and Environment, 8(1):21-25
[59.] Islas-Osuna, M. A., Stephens-Camacho, N. A. and Contrerasvergara, C. A., Rivera-Dominguez, M., Sanchesz-Sanchez, E., Villegas-Ochoa, M. A. and Gonzalez-Aguilar, G. A. (2010). Novel postharvest treatment reduces ascorbic acid losses in Mango (Mangifera indica L.) Var.kent. American Journal of Agriculture and Biology Science, 5 (3): 342-349
[60.] Mgaya-Kilima, B., Remberg, S. F., Chove, B. E. and Wicklund, T. (2014). Influence of storage temperature and time on the physiochemical and bioactive properties of roselle-fruit juice blends in plastic bottle. Food science and nutrition, 2 (2): 181-191
[61.] Falada, K. O., Babalola, S. O., Akinyemi, S. O. S. and Ogunlade, A. A. (2004). Degradation of quality attributes of sweetened juice and Ogbomosho mango juice during storage. European Food Research Technology, 218: 456-459
[62.] Masamba, K. G. and Mndalira, K. (2013). Vitamin C stability in pineapple, guava and baobab juice under different storage conditions using different levels of sodium benzoate and metabisulphite. African Journal of Biotechnology, 12 (2): 186-191
[63.] Jawaheer, B., Goburdhum, D. and Ruggoo, A. (2003). Effect of processing and storage of guava into jam and juice on the Ascorbic acid content, Plant Foods Human Nutrition, 58: 1-12
[64.] Alaka, O. O., Aina, J. O. and Falade, K. O. (2003). Effect of storage conditions on the chemical attributes of Ogbomoso mango juice. European Journal of Food Reservation Technology, 218: 79-82.
[65.] Food and Agriculture Organization/World Health Organization (FAO/WHO) 2001. Human vitamin and mineral requirements Report of a Joint FAO/WHO Expert Consultation.
[66.] Jitareet, P., Paumchai, S. and Kanlayanarat, S. (2007). Effect of chitosan on ripening enzymatic activity and disease development in mango (Mangifera indica L.) fruit, New Zealand Journal of Crop Horticulture Science, 35: 211-218
[67.] Famiani, F., Battistelli, A., Moscatello, S., Cruz-Castillo, J. G. and Walker, R. P. (2015). The organic acids that are accumulated in the flesh of fruits: occurrence, metabolism and factor affecting their contents- A review. Revista Chapingo Serie Horticultura, 21: 97-128
[68.] Hu, Z., Tang, C., He, Z., Lin, J. and Ni, Y. (2017). 1-methylcyclopropene (MCP)-containing cellulose paper packaging for fresh fruit and vegetable preservation, 'Reviewer of MCP in packaging,' BioResources 12(1): 2234-2248
[69.] Khajrul Islam, M. D., Khan, M. Z. H., Sankar, M. A. R.., Nurul, A. and Sarkar, S. K. (2018). Changes in acidity, TSS, and sugar content at different storage periods of the postharvest Mango (Mangifera indica L.) influenced by Bavistin DF, International Journal of Food Science, 2013: 339-385, http://dx.doi.org/10.1155/2013/939385
[70.] Rodriguez pleguezuelo, C. R., Duran Zuazo, V. H., Muriel Ternandez, J. L. and Franco Tarifa, D. (2012). Physico-chemical quality parameters of Mango (Mangifera indica L.) fruits grown in a Mediterranean subtropical climate (SE Spain), Journal of Agricultural Science and Technology, 14:365-374
[71.] Ahmed, M. and Tariq, M. (2014). Enhancing postharvest storage life of tomato (Lycopersicon escudention Mill) C.V Rio Grandi using calcium chloride, American Eurasian Journal of Agriculture and Environmental sciences, 14 (2):143-149
[72.] Gupta, N., and Jain, S. K. (2014). Storage behaviour of mango as affected by postharvest application of plact extracts and storage conditions. Journal of Food Science and Technology, 51 (10): 2499-2507
[73.] Hernandez, Y., Lobo, M. G. and Gonzalez, M. (2006). Determination of vitamin C in tropical fruits: A comparative evaluation of methods. Food Chemistry, 96 (4): 654-664
[74.] Marin, A., Colonna, A., Kudo, K., Kupferman, E. and Matheis, J. (2009). Consumer response to 'Gala' apples treated with 1-methylcyclopropene (1-MCP). Postharvest biology and Technology, 51: 73-79
[75.] Beckles, D. (2012). Factors affecting the postharvest soluble solids and sugar content of tomato (Solanum lycopersium L.) fruit. Postharvest Biology and Technology, 63: 129-140
[76.] Hernandez-Munoz, P., Almenar, E., Ocio, M. J. and Gavara, R. (2006). Effect of Calcium dips and chitosan coatings on postharvest life of straroberries (Fragaria ananassa), Postharvest Biology and Technology, 39: 247-253
[77.] Basetto, E., Jacomino, A. P., Pinheiro, A. L. and Kluge, R. A. (2005). Delay of ripening of 'pedro sato' guava with 1-Methylcyclopropane. Postharvest Biology and Technology, 35: 303-308
[78.] Selvarajab, S., Bauchot, A. and John, P. (2001). International browing in cold-stored pineapples is suppressed by a postharvest application of 1-methylcyclopropene. Postharvest Biology and Technology, 23:167-170

[79.] Dong, L., Lurie, S. and Zhou, H. (2002). Effect of 1-Methylcyclopropene on ripening of 'Canino' apricots and 'Royal Zee' plums, Postharvest Biology and Technology, 24:135-145
[80.] Kirandeep, K., Dhiillon, W. S. and Mahajan, B. V. C. (2013). Effect of different of packaging materials and storage intervals on physical and biochemical characteristics of pear, Journal of Food Science and Technology, 50 (1):147-152
[81.] Genanew, T. (2013). Effect of postharvest treatments on storage behaviour and quality of tomato fruits, World Journal of Agricultural Sciences, 9 (1): 29-37
[82.] Tefera, A., Seyoum, T. and Woldetsadik, K. (2007). Effect of disinfection, packaging and storage environment on the shelf life of mango, Biosystems Engineering, 96 (2): 201-212.
[83.] Pinto, A. C., Alues, R. E. and Pereira, E. C. (2004). Efficiency of different heat treatment procedures in controlling disease of mango fruits. Proceeding, seventh inter mango symposium, Acta Horticulture, 645:551-553
[84.] Dharmasenal, D. A. and Kumari, A.H. (2005). Suitability of charcoal-cement passive evaporative cooler for banana ripening, Journal of Agriculture Science, 1: 1-10
[85.] Salvador, A., Sanz, T. and Fiszman, S. M. (2006). Changes in colour, texture and their relationship with eating quality during storage of two different dessert bananas, Postharvest Biology and Technology, 43:19-325
[86.] Weichmann, J. (1987). Postharvest physiology of vegetables, Marcel Becker, Inc, New York, p145
[87.] Sothornvit, R.. and Rod Samran, P. (2008). Effect of a Mango film on quality of whole and minimally processed mangoes, Postharvest Biology and Technology, 47 (3): 407 -415
[88.] Golding, J. B., Ekman, J. H. and MC Glasson, W. B. (2005). Regulation of fruit ripening: Stewart postharvest Review, Postharvest Biology Technology, 3:1-5
[89.] Pal, R. K. and Roy, S. K. (1988). Zero energy cool chambers for maintaining postharvest quality of carrot (Damcus carota Var. sativa) Indian Journal of Agricultural Science, 58: 665-667
[90.] Rosa, C. I. L. F., Clemente, E., Oliveira, D. M., Todisco, K. M. and Costa, J. M. C. (2016). Effects of 1-MCP on postharvest quality of the orange cv. Pera stored under refrigeration. Revista Ciència Agronòmica, 47(4):624-632
[91.] Zucoloto, M., Ku, K. M., Kim, M. J. and Kushad, M. M. (2017). Influence of 1-methylcyclopropene treatment on postharvest quality of four scab (venturia inaequalis)- resistant Apple cultivars, Journal of Food Quality, 217:595.