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Effect of 1-Methylcyclopropene Treatments and Packaging Material on Proximate Quality of Two Mango (*Mangifera indica L.*) cv. Broken and Dausha Stored under Controlled Temperatures

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ABSTRACT

The mango (*Mangifera indica L.*) is a climacteric fruit which exhibit postharvest losses due to its high ability to lose chlorophyll, unmask other pigments, produce ethylene and hydrolyse insoluble pectin. It therefore, requires special postharvest treatments to extend its shelf life. The study was undertaken under controlled temperature to determine the effect of 1-methylcyclopropene (1-MCP) and packaging material on the proximate attributes of two mango cultivars namely Broken and Dausha grown in Gboko, Benue State, Nigeria. The two mango cultivars were harvested at green-mature stage and treated with four concentrations of 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 days at 11, 13, 15 and 29 °C. Treatments were laid out in factorial arrangement in randomized complete design (RCD) with three replications. The results showed high retention of moisture, crude protein, crude fibre, crude fat, total ash and total carbohydrate contents in the 1-MCP treated and packaged mango samples. Better quality attributes and longevity was observed in Dausha mango samples. The untreated and unpackaged had greater postharvest losses and shorter storage life of only 15 days. The optimum 1-MCP concentration observed for the preservation of Broken and Dausha was 5000 ppb while the optimum storage temperature was 11 °C. Dausha lasted for more than 90 days while Broken 75 days. The research findings show that 1-MCP and packaging material could be used alone or combined to extend the shelf life and maintain the nutritional quality of mango fruit for months under controlled temperatures.

Keywords: 1-methylcyclopropene, Mango fruit, Controlled temperatures, Packaging material, 'Broken' and 'Dausha' mangoes

INTRODUCTION

The mango (*Mangifera indica* L.) is a tropical and sub-tropical fruit tree which originated in India and Burma (Ajila *et al*., 2010). It is one of the most popular fruits liked for its nutritional value, juice, flavour, fragrance and colour (Sakhale *et al*., 2017). Due to these much liked characteristics; it is known as the King of fruit in the Indian sub-continents (Abdalla *et al*., 2016). Mango production has also increased in non-traditional mango producing areas which include parts of Asia, West Africa, Australia, South America and Mexico (Kostermans and Bompard, 1993). In 2003, 26.19 million metric tonnes of mango fruit were produced in the world from an area of 3.44 million hectares (Budhwar, 2002). The annual mango production in Nigeria is estimated at around 8.5 million metric tonnes (FAO, 2014). When compared to other countries, Nigeria ranks 9th in the world top 10 mango producing countries (FAO, 2014). The main mango producing states in Nigeria include Benue, Jigawa, Plateau, Yobe, Kebbi, Niger, Kaduna, Kano, Bauchi, Sokoto, Adamawa, Taraba and Federal Capital Territory (FCT), Abuja (FAO, 2014). There are about 1000 mango varieties grown worldwide, but the varieties common in Nigeria are: Alphonso, Zill, Julie, Palmer, Lippens, Saigon, Edward, Haden, Kerosene, Hindi, Dausha, Peter, John, Broken, Early gold and some other local varieties (Ubwa *et al.,* 2014). The commercial varieties commonly grown in Benue State include Hindi, Dausha, Peter, Julie, John, Broken and local mango (Ubwa *et al.,* 2014).

Mangoes are highly nutritious fruit containing carbohydrates, proteins, fats, fibre, minerals and vitamins. The most common vitamins in mango are vitamin A (β-carotene), B_1, B_2 (riboflavin) and vitamin C (ascorbic acid) (Bally, 2006). Because of these attributes, mango is highly demanded both locally and internationally by consumers. However, mango exhibit high postharvest losses and hence short shelf life. This is due to the high endogenous and exogenous ethylene development which accelerates respiration and ripening and consequently maturity. This is followed by softening and senescence of the fruit, thereby decaying a few days after postharvest storage under ambient temperature (Pauziah and Ikwan, 2014). Under commercial practice, transportation of fresh mango fruit to distant markets without proper preservation, packaging and storage methods results to more tremendous losses. However, reliable statistical data are inadequate especially in Nigeria to indicate the magnitude of postharvest losses of mango. It is believed that postharvest losses of mangoes in Nigeria may be as high as 30-40 % due to poor postharvest handling.

The postharvest losses and short shelf life of mango is attributed to ethylene which is a gaseous natural plant hormone that plays multiple roles in regulating plant growth and development, and is a key modulator of the response to biotic or abiotic stresses (Harper, 2015). When ethylene binds to a receptor, a signal is transduced through a complex mechanism to trigger specific biological processes that eventually lead to the regeneration of ethylene and the ripening of fruit (Giovannoni, 2007). To overcome these problems it is necessary to find techniques that would extend the shelf life of mango fruit and minimize postharvest losses while maintaining the quality. Being a climacteric fruit, extending the shelf life of mangoes as well as maintaining the quality leads to reduction in ethylene levels and as such blocking its adverse postharvest effects. Therefore, the development of technologies to extend postharvest life of mango fruit require approaches aimed at blocking the ethylene receptor site. This subsequently leads to delay in ethylene dependent responses.

A number of methods/technologies are in use to inhibit ethylene for the preservation of fruit and vegetables. Among these, 1-methylcycloproprene (1-MCP) is the most potent. 1-MCP is a gas at room temperature and pressure. The strength to which 1-MCP binds to the ethylene receptor cell is about 10 times more than ethylene itself and is more active at low concentrations. It has no detectable odour and has not been reported to have any toxic properties (Romero *et al.,* 2007). 1-MCP is known to have no residue within 24 h of application (Harper, 2015). It has been known to extend the shelf life and maintain the quality of various climacteric fruit such as apples, tomatoes, kiwis, bananas and melons. This is achieved by blocking the ethylene receptor sites, thereby preventing the binding of endogenous and exogenous ethylene and its negative effects (Watkins, 2010). Mango is among the crops registered for 1-MCP treatment (Watkins, 2006) and positive effects of 1-MCP on several cultivars have also been reported (Siva *et al.,* 2004, Wang *et al.,* 2009, Nghiem and Shiesh, 2010). The application of 1-MCP at different concentrations, storage durations and controlled temperatures to extend shelf life and delay quality deterioration processes in tropical fruit have also been reported (Razali *et al.,* 2007b, Ding and Darduri, 2009, Ali and Mamat, 2010). Packaged fruit have been reported to show reduced physiological weight loss, higher pH and titratable acid content than non packaged mango fruit (Alye, 2005). Similarly, modified atmosphere packaging (MAP) has also been reported to affect the postharvest quality of mango (Siva *et al.,* 2004, Alye, 2005).

At present, there has been increasing research interest concerning the preservation, packaging and storage of climacteric fruit 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 separate or combined effects of 1-MCP and packaging material under controlled temperatures on the postharvest ripening, shelf life and proximate quality attributes of mango fruit.

MATERIALS AND METHODS

Study Area

The study area Gboko, lies within latitude 6^{o} $28^{"}$ to 8^{o} $13^{"}$ N and longitude $8^{o}04^{"}$ to 9^{o} $16^{"}$ E. It is located in the North Central Zone of Nigeria. People in this area produce different mango fruit varieties for regional consumption in large amounts.

Experimental Design

The experiment was conducted in the month of May through August 2018. Two mango cultivars (Dausha and Broken) were used to investigate the effect of 1-MCP concentration, storage temperature, fruit variety, corrugated paperboard (CPB) packaging and storage time. Sampling of fruit from the orchards was made in a completely randomized design (CRD) with three replications. The treatments were arranged in a factorial scheme and followed 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 ^{o}C -ambient temperature), two types of packaging (packaged with corrugated paperboard and unpackaged) and two mango

varieties (Dausha and Broken). The fruit were observed for 90 days and quality evaluation was carried out for every 15 days interval (15, 30, 45, 60, 75 and 90).

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 °C (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 = 4x4x2x2x6 =384 samples

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Sample Collection

A sample size consisting of 384 mature green mango fruit was collected from the two orchard farms, Mtswenen Tyo farm, behind new 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 if firm with no depression when thumb-pressed and visual 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) (Mamiro *et al.,* 2007). The samples were properly identified by a Botanist and clean open air plastic containers were used in transporting samples to the Chemistry laboratory, Benue State University, Makurdi, Nigeria.

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.

Sample treatment with 1-MCP

Out of the 384 mango fruit, 288 were labelled according to the three concentrations of 1-MCP (1000, 3000 and 5000 ppb). Thereafter, they were grouped into three equal lots of 96 fruit. These lots with equal number of Broken and Dausha 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 °C for 24 h for the reaction to complete. The other 96 fruit (control) were labelled and kept on the laboratory bench till after 24 h to be stored at the same time with the treated fruit.

Packaging and storage

A total of three hundred and eighty four (384) fruit were used. One hundred and ninety two (192) fruit (Broken and Dausha) were packaged in thirty two (32) corrugated paperboard boxes consisting of six (6) fruit per box based on the concentration of 1-MCP. The other one hundred and ninety two (192) fruit were preserved without packaging. All the fruit were stored for ninety (90) days at 11, 13, 15 and 29 °C (ambient temperature) for quality evaluation. The quality evaluation was performed six times at day 15, 30, 45, 60, 75, and 90 of storage.

Proximate analysis

Proximate analysis was carried out using standard analytical procedures to determine the moisture content, crude fat, crude protein, ash, crude fibre and total carbohydrate. Triplicates determinations were carried out for each of the parameters.

Determination of moisture content

Moisture content was determined using Method 925.09 of AOAC (2005). The crucible was dried in an air oven (Genlab Oven, model: OVE2050) at 105 °C for 30 min. Thereafter; it was allowed to cool in the desiccator and weighed (w_1). 2.0000 g of the sample were weighed using analytical balance (ADAM, model: pw184) and the weight of the sample plus the crucible was taken (w_2). The crucible with the sample was dried at 105 °C for 3 h. The crucible was removed, cooled in desiccator and weighed. The process of drying, cooling and weighing was repeated until a constant weight (w_3) was obtained and the weight loss due to moisture was obtained by the equation

$$\%\text{Moisture} = \frac{w_2 - w_3}{w_2 - w_1} \times 100 \quad 3$$

Determination of ash

Ash content was determined using Method 923.03 of AOAC (2005). The crucible was placed in the muffle furnace (Bark Meyer Muffle furnace, Model: NEY M-525 SII) regulated at 600 °C for 30 min. It was transferred to the desiccator and weighed when cool (w_1). 5.0000 g of sample were weighed using analytical balance (ADAM, model: pw184) and transferred to the crucible. The weight of the sample and crucible was accurately recorded (w_2). The crucible with the sample was placed inside the muffle furnace (Bark Meyer Muffle furnace, Model: NEY M-525 SII) and heated to grey ash for 3- 4 h. The crucible was cooled in a desiccator and weighed soon after reaching room temperature and until constant weight was obtained (w_3).

$$\%\text{ Ash Content} = \frac{w_3 - w_1}{w_2 - w_1} \times 100 \quad 4$$

Determination of crude fat

Fat content was determined following Method 920.39 of AOAC (2005). Exactly 2.0000 g of the sample were weighed (w_1) using analytical balance (ADAM, model: pw184) and transferred into a pre weighed thimble and covered with a clean glass wool. The weight of the thimble and the sample before extraction was taken. The thimble was transferred into the soxhlet extractor and extracted for 6 h using 500 mL of petroleum ether (40-60 °C) in a pre-weighed round bottom flask (w_2). The flask containing the crude fat extract was disconnected from the soxhlet extractor and the solvent evaporated from the extract. The flask was oven dried at 100 °C for 24 h to remove all the solvent. Thereafter, it was allowed to cool to room temperature and then transferred to the desiccator to cool. This process was repeated until a constant weight was obtained (w_3). The percentage fat was calculated using the equation below.

$$\%\text{ Crude fat} = \frac{w_3 - w_2}{w_1} \times 100 \quad 5$$

Determination of crude fibre

Crude fibre was determined following Method 962.09 of AOAC (2000). The residue left after the extraction of the fat content was used for the determination of crude fibre. Exactly 2.0000 g of the fat free materials was weighed (w_1) using analytical balance (ADAM, model: pw184) and transferred into the spoutless beakers and boiled water was added alongside 25 mL of 10 % sulphuric acid and made up to 200 mL mark. The mixture was boiled for 30 min and filtered using a suction pump. The residues obtained were washed with boiling water for at least three to four times and transferred back to the beaker. Boiling water was added again followed by the addition of 25 mL of 10 % NaOH and made up to the 200 mL mark. It was boiled again for 30 min and filtered using a suction pump. The residues obtained were dried in the oven and weighed (w_2). The residues were incinerated at 600 °C for 3 h in a muffle furnace (Bark Meyer Muffle furnace, Model: NEY M-525 SII) to oxidise off the crude fibre. It was finally cooled in a desiccator and weighed again (w_3). The amount of the crude fibre in the sample was calculated by subtracting the weight of the ash from the weight of the residue. The crude fibre content was expressed as percentage

loss in weight on ignition using the equation below.

$$\% \text{ Crude fibre} = \frac{w_2 - w_3}{w_1} \times 100 \quad 6$$

Determination of crude protein

Digestion

The crude protein was determined using Method 920.87 of AOAC (2005). Exactly 2.0000 g of the sample was accurately weighed using analytical balance (ADAM, model: pw184) and transferred into the Kjeldahl digestion flask. 8.0000 g of the digestive or catalyst mixture (96 % Na_2SO_4 and 4 % $CuSO_4$) was weighed using the same balance above and transferred into a dry 300 mL Kjeldahl flask. 2 glass beads were added to prevent the solution from bumping and 20 mL of concentrated H_2SO_4 also added. The flask with the content was heated on a heating mantle initially at low temperature to prevent frothing and later boiled briskly until the solution became clear and free from carbon or until there was complete oxidation. After the solution became clear, digestion was proceeded for another one hour to complete the breakdown of all organic matter.

This process converts the nitrogen in the food, other than nitrate and nitrite nitrogen, into ammonium sulphate:

$$N(food) \rightarrow (NH_4)_2 SO_4 \quad 7$$

Distillation

A 250 mL Erlenmeyer flask containing 50 mL of 4 % boric acid with indicator as receiver of the distillation unit. The content of the Kjeldahl flask was allowed to cool and thereafter diluted with 200 mL of distilled water. Exactly 70 mL of 50 % NaOH was added slowly by the side of the flask without shaking. The addition of 50 % NaOH solution turned the solution to slightly alkaline and ammonia gas was liberated.

$$(NH_4)_2 SO_4 + 2NaOH \rightarrow 2NH_3 + 2H_2O + Na_2SO_4 \quad 8$$

This was distilled until all the ammonia was released or 150 mL distillate was obtained. During distillation, the tip of the delivery tube was lowered below the liquid surface of the receiver flask containing 50 mL of 4 % boric acid to trap all the ammonia gas into solution.

$$2\,NH_3 + 2\,H_3BO_3 \rightarrow 2\,NH_4H_2BO_3 \quad 9$$

Finally, the delivery tube was rinsed with distilled water and all the washings were allowed to drain into the flask.

Titration

The ammonium borate formed was estimated by titrating with standardised 0.1M hydrochloric acid until the first appearance of the pink colour. The volume of acid was recorded to the nearest 0.05 mL.

$$2\,NH_4H_2BO_3 + 2\,HCl \rightarrow 2\,NH_4Cl + 2\,H_3BO_3 \quad 10$$

Adding equation (9) and (10) gives the overall reaction for the titration

$$2NH_3 + 2HCl \rightarrow (NH_4)_2 2NH_4Cl \quad 11$$

Calculation

Protein was calculated using the formula below:

$$\text{N}(\%) = \frac{(mL\,0.1M\,HCl_{sample} - 0.1\,\text{M HCl}_{blank}) \times 0.0014}{Weight\ of\ sample} \times 100 \quad 12$$

$$\text{Protein (g per 100 g)} = \% \text{ total nitrogen} \times 6.25 \quad 13$$

Determination of carbohydrate

The James' method (1995) was adopted where the total proportion of carbohydrate in the mango sample was obtained by calculating the percentages of food nutrients: % moisture, % protein, % crude fats, % crude fibre and % ash and subtracting from 100 %.

$$\%Cx(H_2O)y = 100\% + (\%\text{moisture} + \%\text{ protein} + \%\text{ crude fats} + \%\text{crude fibre} + \%\text{ ash} \quad 14$$

Data 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 comparison. The GENSTAT statistical package was used. (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.

RESULTS AND DISCUSSION

The results of proximate composition of Broken and Dausha treated with 0 ppb, 1000 ppb, 3000 ppb, and 5000 ppb 1-MCP concentrations and stored at controlled temperatures of 11, 13, 15 and 29 °C (ambient temperature) are presented in Tables 1-6. The parameters determined were: moisture, protein, fibre, fats, ash and carbohydrate for day 15, 30, 45, 60, 75 and 90. They were significantly affected ($p<0.05$) by 1-MCP concentration, packaging, storage temperature and time.

Moisture

There was significant difference ($p<0.05$) in moisture content of the mango with the application of 1-MCP concentrations throughout the storage period except on day 15 (Table 1). The moisture content of the mango fruit samples were retained significantly with 1-MCP concentration, packaging, storage temperature and cultivar. However, the combined effect of concentration and variety had no significant effect ($p>0.05$) on moisture content. The control had the lowest moisture content (70.04 %) compared with the other samples. The 5000 ppb 1-MCP treated mango had the highest moisture content of 75.20 %. There was decrease in the rate of loss in moisture with the application of 1-MCP concentration which could be due to its ability to delay/inhibit ripening and senescence processes. The result also indicate variations in moisture content among cultivars when subjected to similar treatments, which could be due to difference in genetic, physiological and maturity stage during harvest.

There was also a significant difference ($p<0.05$) between moisture content and storage temperature after day 15 of storage, decreasing with storage temperature and time (Table 1). The highest moisture content recorded (75.27 %) was at 11 °C and the lowest (70.07 %) at 29 °C. The rate of moisture loss at higher temperature was greater than that at lower temperatures. The low temperature and high humidity prevalent in cold storage might be responsible for retarding respiration thus reducing moisture loss (Zhu *et al.,* 2008). These findings are in agreement with the report of Sothornvit and Rodsamran (2008) that cold storage considerably retards moisture loss of mangoes in comparison with ambient and elevated storage temperatures. Interestingly, only mango fruit stored at 11 °C lasted up to 90 days, contrary, mangoes stored at 13, 15 and 29 °C had shelf lives of only 45, 30 and 15 days respectively. Generally, there was a linear increase in moisture loss irrespective of storage temperature with prolonged storage time.

Packaging had significant effect ($p<0.05$) on moisture content of mango fruit throughout the storage period (Table 1). Moisture content decreased linearly across the storage period irrespective of treatment. Mango fruit stored in paper board packaging maintained more moisture (75.24 %) than the unpackaged (73.71 %). As earlier observed, higher relative humidity and modified atmosphere created within the package were possible causes of the significant delay in moisture loss of packaged mango fruit. It has been reported that faster air movement around unpackaged fruits could result in higher water loss (Zhu *et al.,* 2008).

Significant differences ($p<0.05$) were observed with regard to moisture content and cultivars

Table 1: Moisture content (%) of Broken and Dausha mango as affected by 1-MCP concentration (ppb), storage temperature (°C), packaging and variety during storage period of 90 days

Variables		Storage period (days)					
		15	30	45	60	75	90
1-MCP	0 (control)	70.04±0.02	-	-	-	-	-
	1000	74.35±0.05	73.12±0.03	73.17±0.02	72.47±0.08	-	-
	3000	75.18±0.03	75.00±0.03	74.56±0.01	74.35±0.05	73.80±0.04	72.04±0.03
	5000	75.20±0.01	75.15±0.00	75.04±0.00	74.39±0.07	74.00±0.01	73.97±0.11
LSD(p≤0.05)		0.21	0.01	0.01	0.01	0.01	0.01
ST	11	75.27±0.04	75.19±0.01	75.06±0.01	74.68±0.05	74.41±0.00	74.20±0.01
	13	75.00±0.01	74.78±0.03	73.45±0.04	-	-	-
	15	74.55±0.03	73.37±0.01	-	-	-	-
	29	70.07±0.02	-	-	-	-	-
LSD (p≤0.05)		0.21	0.01	0.01	*	*	*
PB	Packaged	75.24±0.05	75.10±0.02	75.16±0.03	75.08±0.02	74.05±0.01	73.18±0.07
	Unpackaged	73.71±0.03	73.64±0.03	71.25±0.05	-	-	-
LSD (p≤0.05)		0.15	0.01	0.01	*	*	*
Cultivars	Broken	75.19±0.10	74.51±0.00	73.65±0.01	72.03±0.00	70.27±0.00	-
	Dausha	75.20±0.00	75.12±0.11	75.05±0.11	74.71±0.03	74.48±0.00	73.56±0.01
LSD (p≤0.05)		0.01	0.01	0.01	0.02	0.02	*
	SE	0.53	0.02	0.01	0.11	0.01	0.01
	CV (%)	0.70	0.00	0.00	0.00	0.00	0.00
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

*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 compared 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*

Table 2: Protein content (%) of Broken and Dausha mango as affected by 1-MCP concentration (ppb), storage temperature (°C), packaging and variety during storage period of 90 days

Variables		Storage period (days)					
		15	30	45	60	75	90
1-MCP	0 (control)	2.68±0.00	-	-	-	-	-
	1000	2.49±0.03	2.49±0.11	2.43±0.04	2.28±0.01	-	-
	3000	2.43±0.02	2.44±0.05	2.42±0.02	2.47±0.01	2.46±0.02	2.30±0.02
	5000	2.34±0.06	2.38±0.02	2.36±0.01	2.45±0.03	2.43±0.03	2.40±0.01
LSD (p≤0.05)		0.03	0.00	0.00	0.01	0.02	0.02
ST	11	2.40±0.02	2.44±0.04	2.43±0.01	2.46±0.07	2.44±0.01	2.41±0.05
	13	2.44±0.11	2.41±0.06	1.81±0.04	-	-	-
	15	2.46±0.03	2.46±0.03	-	-	-	-
	29	2.71±0.05	-	-	-	-	-
LSD (p≤0.05)		0.03	0.01	0.01	*	*	*
PB	Packaged	2.38±0.02	2.36±0.10	2.44±0.11	2.46±0.01	2.43±0.00	2.40±0.01
	Unpackaged	2.54±0.07	2.48±0.03	1.80±0.00	-	-	-
LSD (p≤0.05)		0.01	0.01	0.03	*	*	*
Cultivars	Broken	2.42±0.01	2.53±0.02	2.49±0.10	2.16±0.03	1.14±0.00	-
	Dausha	2.38±0.03	2.41±0.00	2.44±0.06	2.47±0.04	2.42±0.06	2.41±0.01
LSD (p≤0.05)		0.02	0.00	0.00	0.01	0.02	*
	SE	0.07	0.01	0.01	0.01	0.01	0.01
	CV (%)	2.90	0.20	0.30	0.30	0.50	0.30
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

*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 compared with any at this level. Values are presented as Means±Standard Deviations (n=6); S, significant at p<0.05 level*

Table 3: Fibre content (%) of Broken and Dausha mango as affected by 1-MCP concentration (ppb), Storage temperature (°C), packaging and variety during storage period of 90 days

Variables		Storage period (days)					
		15	30	45	60	75	90
1-MCP	0 (control)	1.12±0.01	-	-	-	-	-
	1000	0.95±0.02	0.95±0.05	0.98±0.04	1.13±0.10	-	-
	3000	0.92±0.04	0.93±0.01	0.96±0.03	0.97±0.01	1.05±0.00	1.12±0.02
	5000	0.91±0.00	0.91±0.00	0.94±0.00	0.96±0.02	0.98±0.02	1.22±0.02
LSD (p≤0.05)		0.00	0.00	0.01	0.01	0.76	0.03
ST	11	0.90±0.08	0.90±0.02	0.91±0.01	0.93±0.03	0.94±0.01	0.96±0.00
	13	0.91±0.02	0.92±0.06	0.97±0.00	-	-	-
	15	0.93±0.10	0.95±0.05	-	-	-	-
	29	1.15±0.10	-	-	-	-	-
LSD (p≤0.05)		0.00	0.00	0.01	0.01	0.01	0.03
PB	Packaged	0.90±0.03	0.90±0.11	0.92±0.10	0.89±0.01	0.93±0.03	0.94±0.02
	Unpackaged	1.00±0.00	1.02±0.02	1.10±0.08	-	-	-
LSD (p≤0.05)		0.00	0.00	0.01	*	*	*
Cultivars	Broken	1.00±0.03	1.10±0.04	1.12±0.01	1.14±0.01	1.13±0.02	-
	Dausha	0.93±0.10	0.95±0.02	0.92±0.02	1.00±0.02	1.04±0.04	1.07±0.01
LSD (p≤0.05)		0.00	0.00	0.01	0.01	0.01	*
	SE	0.01	0.01	0.01	0.01	0.57	0.01
	CV (%)	1.10	0.80	1.60	0.90	46.20	1.00
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

*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 compared with any at this level. Values are presented as Means±Standard deviations (n=6); S, significant at p<0.05 level*

Table 4: Fat content (%) of Broken and Dausha mango as affected by 1-MCP concentration (ppb), storage temperature (°C), packaging and variety during storage period of 90 days

Variables		Storage period (days)					
		15	30	45	60	75	90
1-MCP	0 (control)	0.20±0.06	-	-	-	-	-
	1000	0.29±0.01	0.30±0.00	0.26±0.01	0.24±0.00	-	-
	3000	0.30±0.11	0.28±0.02	0.29±0.02	0.28±0.06	0.26±0.07	0.24±0.10
	5000	0.34±0.01	0.32±0.04	0.30±0.00	0.30±0.01	0.29±0.03	0.26±0.00
LSD (p≤0.05)		0.01	0.01	0.01	0.01	0.03	0.02
ST	11	0.34±0.00	0.32±0.00	0.31±0.02	0.29±0.00	0.30±0.01	0.28±0.00
	13	0.26±0.02	0.24±0.03	0.22±0.03	-	-	-
	15	0.22±0.04	0.20±0.11	-	-	-	-
	29	0.21±0.01	-	-	-	-	-
LSD (p≤0.05)		0.01	0.01	0.01	*	*	*
PB	Packaged	0.33±0.05	0.32±0.05	0.30±0.02	0.29±0.01	0.31±0.02	0.28±0.01
	Unpackaged	0.26±0.03	0.24±0.03	0.21±0.05	-	-	-
LSD (p≤0.05)		0.00	0.01	0.01	*	*	*
Cultivars	Broken	0.25±0.01	0.26±0.02	0.26±0.00	0.25±0.05	0.22±0.05	-
	Dausha	0.34±0.06	0.35±0.11	0.32±0.10	0.30±0.06	0.29±0.06	0.26±0.02
LSD (p≤0.05)		0.00	0.01	0.01	0.01	0.03	*
	SE	0.01	0.02	0.03	0.01	0.02	0.01
	CV (%)	0.40	0.60	1.20	0.30	0.90	0.40
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

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 compared with any at this level. Values are presented as Means±Standard deviations (n=6); S, significant at p<0.05 level

Table 5: Ash content (%) of Broken and Dausha mango as affected by 1-MCP concentration (ppb), storage temperature (°C), packaging and variety during storage period of 90 days

Variables		Storage period (days)					
		15	30	45	60	75	90
1-MCP	0 (control)	0.92±0.02	-	-	-	-	-
	1000	0.91±0.00	0.98±0.05	0.94±0.04	0.91±0.04	-	-
	3000	0.94±0.04	0.92±0.02	0.95±0.01	0.95±0.01	0.90±0.01	0.96±0.00
	5000	0.96±0.01	0.93±0.01	0.96±0.00	0.91±0.03	0.92±0.00	0.90±0.04
LSD(p≤0.05)		0.01	0.00	0.00	0.01	0.02	0.01
ST	11	0.98±0.03	0.95±0.03	0.93±0.01	0.98±0.10	0.97±0.00	0.95±0.02
	13	0.94±0.05	0.96±0.11	0.92±0.02	-	-	-
	15	0.97±0.11	0.94±0.00	-	-	-	-
	29	0.93±0.04	-	-	-	-	-
LSD(p≤0.05)		0.03	0.02	0.01	*	*	*
PB	Packaged	0.98±0.02	0.95±0.04	0.94±0.03	0.92±0.03	0.97±0.06	0.92±0.01
	Unpackaged	0.97±0.01	0.96±0.06	0.95±0.02	-	-	-
LSD(p≤0.05)		0.01	0.01	0.01	*	*	*
Cultivar	Broken	0.92±0.01	0.94±0.03	0.93±0.02	0.93±0.02	0.91±0.02	-
	Dausha	0.97±0.01	0.98±0.02	0.95±0.00	0.96±0.00	0.96±0.02	0.92±0.01
LSD(p≤0.05)		0.01	0.01	0.01	0.02	0.02	*
	SE	0.01	0.01	0.01	0.02	0.01	0.01
	CV (%)	0.80	0.70	0.80	2.60	1.80	1.40
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

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 compared with any at this level. Values are presented as Means±Standard deviations (n=6); S, significant at p<0.05 level

Table 6: Carbohydrate content (%) of Broken and Dausha mango as affected by 1-MCP concentration (ppb), storage temperature (°C), packaging and variety during storage period of 90 days

Variables		Storage period (days)					
		15	30	45	60	75	90
1-MCP	0 (control)	10.57±0.01	-	-	-	-	-
	1000	13.63±0.00	12.21±0.00	10.27±0.01	8.33±0.11	-	-
	3000	15.77±0.02	15.47±0.11	15.50±0.04	14.62±0.05	14.28±0.03	12.61±0.02
	5000	20.11±0.11	19.26±0.05	16.06±0.11	15.75±0.07	15.22±0.04	14.05±0.01
LSD(p≤0.05)		0.20	3.03	0.02	0.04	0.18	0.05
ST	11	20.30±0.03	17.03±0.03	16.45±0.01	15.89±0.00	15.24±0.02	14.15±0.01
	13	14.68±0.05	10.22±0.02	9.16±0.00	-	-	-
	15	11.40±0.02	8.52±0.01	-	-	-	-
	29	9.71±0.01	-	-	-	-	-
LSD(p≤0.05)		0.20	3.03	0.02	*	*	*
PB	Packaged	19.10±0.01	17.88±0.11	16.02±0.02	15.45±0.01	14.18±0.09	14.86±0.02
	Unpackaged	15.14±0.03	12.63±0.03	9.05±0.01	-	-	-
LSD(p≤0.05)		0.14	0.48	0.02	*	*	*
Cultivars	Broken	17.31±0.01	15.78±0.03	12.57±0.00	14.18±0.02	9.94±0.00	-
	Dausha	20.13±0.03	18.74±0.04	16.44±0.02	15.06±0.04	15.76±0.02	14.20±0.01
LSD(p≤0.05)		0.14	2.48	0.02	0.03	0.78	*
SE		0.50	6.46	0.03	0.03	0.58	0.02
CV (%)		2.50	31.90	0.20	0.20	3.90	0.20
Innteraction							
p.1-MCP×ST		NS	NS	S	S	NS	S
p.1-MCP×PB		NS	NS	S	S	NS	S
p.1-MCP×Cultivar		NS	NS	S	S	NS	S

*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 compared 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*

throughout the storage period (Table 1). Dausha mango showed higher retention in moisture content than Broken. The observed differences in moisture could be due to variation in maturity, physiological and physical characteristics between the two cultivars.

Generally, there was a significant interaction effect ($p<0.05$) between 1-MCP concentration and storage temperature, 1-MCP concentration and packaging, 1-MCP concentration and cultivars on the changes in moisture content of the mango fruit throughout the storage period except on day 15 showing that moisture is concentration dependent (Table 1).

Crude protein

The crude protein content of mango fruit was significantly affected ($p<0.05$) by 1-MCP treatments, storage temperature, paper board packaging and cultivars throughout the storage periods (Table 2). The 1-MCP treatments showed significant differences ($p<0.05$) for crude protein content of the mangoes throughout the storage period. The highest crude protein content of 2.68 % was observed in the control sample. This decreased slightly in all the 1-MCP treated to 2.34 %. The protein content decreased with increase in 1-MCP concentration from day 15 to 60 and declining towards the end of storage time (day 75 90). Normally, protein levels increase during ripening of fruit. This may be due to the metabolism of enzymes present in fruit (Onimawo, 2002). Therefore, decrease of protein in 1-MCP treated mango fruit could be attributed to decrease in metabolic rate caused by the effect of 1-MCP. Storage temperature significantly affected ($p<0.05$) the change in protein throughout the storage period (Table 2). The protein content increased with increasing temperature but declined with prolongation of storage time. High temperatures favour enzymatic and metabolic activities which could be the reason for the increase in protein content observed in this study.

Packaging showed significant differences ($p<0.05$) in fruit protein throughout the storage period (Table 2). Packaged mango fruit showed lower protein content and retained protein reasonably during the storage period, whereas unpackaged fruit had higher protein content but turned to depreciate faster with time.

In most of storage periods, significant differences ($p<0.05$) were observed with regard to protein content between cultivars (Table 2). Dausha retained more protein than Broken. The observed protein differences between the mangos imply the disparity in DNAs amid the cultivars. A comparison of the result of this study with the reported literature values of 0.36 - 0.40 g/100g (Bally, 2006) shows that the varieties used in this study had higher protein content. Proteins are very good nutrients for the body and are been referred to as building blocks of the body (Dietzan, 2018). Apart from water and fat, the human body is made up of almost entirely of protein. Protein is the main component of muscles, bones, organs, skin and nails (Dietzan, 2018). The crude protein reported in this study is above EU/WHO (2000) recommended limits of 1 g/100g for fruit group. The values are above 1.97 and 2.16 % reported by Mohammed and Yakubu (2013) but below 7.96 % reported by Arumugan & Manikandan (2011).

Generally, all the interaction terms, concentration of 1-MCP and storage temperature, concentration of 1-MCP and packaging, concentration of 1-MCP and cultivar significantly ($p<0.05$) contributed to change in protein content of the mango fruit (Table 2)

Crude fibre

Significant differences ($p<0.05$) were observed between 1-MCP treatments and the

crude fibre content of mango fruits throughout the storage time (Table 3). The control had the highest crude fibre content (1.12 %) on day 15 while 5000 ppb concentration of 1-MCP had the lowest crude fibre content (0.91 %) on the same day. Crude fibre content naturally increases from unripe fruit (mature green) to ripe due to the activities of metabolic enzymes. The decrease in crude fibre content with increase in 1-MCP concentration may be due to decreased metabolic activities caused by 1-MCP.

Storage temperature had significant effect ($p<0.05$) on the crude fibre content of mango fruit throughout the storage period (Table 3). The crude fibre increased with temperature and storage time. At 11 ^{o}C, the crude fibre content was 0.90 % while at ambient temperature (29 ^{o}C) it was 1.15 %. As earlier observed in other parameters, the low crude fibre recorded at 11 ^{o}C may have been due to the inhibitory action of 1-MCP and the cold storage in delaying metabolic activities.

Packaging significantly affected ($p<0.05$) the change in crude fibre content throughout the storage period (Table 3). Packaged fruit had low fibre content (0.90 %) compared to the unpackaged fruit (1.00 %). This trend was observed throughout the storage period. Higher relative humidity and modified atmosphere created within the packages may have been possible causes for the significant reduction in crude fibre of packaged fruit. Broken and Dausha showed a significant variation ($p<0.05$) in crude fibre content. Broken showed higher crude fibre content (1.00 - 1.13 %) compared to Dausha (0.93 to 1.07 %) throughout the storage period, probably due to genetic and physiological factors.

The crude fibre content in this study is within the range reported (0.85 - 1.06 g/100g) in literature (Bally, 2006). The fibre content obtained is similar to those obtained by Abourayya *et al*., (2011) and higher than 0.70 g/100g and 0.54 - 0.70 g/100g reported by Othman and Mbango (2009) and Gopalan *et al*., (2010) respectively. It has been reported that excess fibre above 50 g per a day may lead to risk of mineral binding such as calcium, magnesium and phosphorus (Meena *et al.,* 2009). Fibre is good for the body as it helps to maintain the health of the gastrointestinal tract, but in excess it may bind trace elements, leading to deficiencies of iron and zinc in the body (Siddhuraju *et al*., 1996). It is also known for its ability to prevent or relieve constipation, normalizes bowel movement, lowers cholesterol levels and help in controlling blood sugar levels (Siddhuraju *et al*., 1996). The crude fibre content reported in the study can contribute meaningfully to the fibre needs of the body.

There was 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 changes in crude fibre of the mango fruit throughout the storage period indicating that crude fibre change is dependent on these variables (Table 3).

Crude fat

Crude fat of the mango fruit was significantly affected ($p<0.05$) by both1-MCP treatment, storage temperature, paperboard packaging and cultivars throughout the storage period (Table 4).

The 1-MCP treatment showed significant difference ($p<0.05$) in the change in crude fat throughout the storage periods. There was a decreased in fat content in the control (0.24 - 0.20 %) and a slight increase in the 1-MCP treated mango fruit (0.29 - 0.34 %) for the first 15 days. Generally, the crude fat content increased with increase in 1-MCP concentration and storage period up to day 60, after which a decrease was noticed. The low decreased in fat content in the 1-MCP treated fruit shows that 1-MCP may have inhibited or caused a decreased in the activity of enzymes that degrade the cell wall of the fruit and lipids. It could also be due to losses in fat occurring in the cell membrane caused by the loss

of phospholipids and weakening of the cellular membrane during fruit ripening and the conversion of lipids to volatile compounds in the synthesis of aroma compounds (Knee, 2002). This effect is also attributed to high rates of ethylene production in fruit during ripening which lead to high enzymatic activity and cell membrane disruption (Gutierrez et al., 2005).

The storage temperature significantly affected ($p<0.05$) the change in fat content of mango fruit throughout the storage periods (Table 4). The fat content of treated mango fruit stored at 29 °C (ambient) was lower (0.21 %). The fat content decreased with increasing storage temperature and time. The result is inline with the findings of Muhammed *et al*., (2012) and Rattannaporn *et al*., (2005) who both reported a decrease in fat content in mangoes stored at ambient temperature with increasing storage time.

Similarly, fruit stored in paperboard packaged retained more fats than those that were stored unpackaged (Table 4). The unpackaged fruit samples were exposed to O_2 leading to increased oxidation, respiration and high level of ethylene production (Wills, 1998) hence rapid decrease in fat content. The observed retention in fat content of the packaged fruit might be due to the retarded respiration resulting from the modified atmosphere (O_2 depletion and CO_2 accumulation) in the packaging materials (Ben-Yehoshua, 1985), which in turn prevented the oxidation of fats. This result is in line with the findings of Hernandez-Moreno *et al.,* (2014) and Cocozza *et al.,* (2004).

Cultivars significantly affected ($p<0.05$) the fat content of the mango fruit throughout the storage periods (Table 4). Dausha recorded a higher fat content (0.34 %) than Broken (0.25 %), and also retained more fat than Broken throughout the storage period. The difference in fat content during storage may be due to genetic factors.

The crude fat content obtained from the pulps of these two mango fruit varieties (Table 4) fall within the values found in literature (0.30 - 0.50 g/100g) (Bally, 2006) but not up to 0.50 g/100g maximum limit recommended by NAFDAC (2010) for fat free foods. However, the values meet the 0.25 g/100g recommended by EU/WHO (2000) for fruit groups. The crude fat content reported in this study is relatively higher than that reported by Ubwa *et al*., (2014) and Othman and Mbogo (2009) but lower than the values reported by Mahammed and Yakubu (2013) and Arumugam and Manikandan (2011). It has been reported that the fat content of fruit should not be greater than 1 % (Norman, 1976). The low lipid concentration in fruit is an indication that the lipids are mobilized and stored in the seeds thereby making this mango fruit a good food for people suffering from obesity (Nwofia *et al.,* 2012). It therefore means that, mango fruit varieties in this study could be recommended for people suffering from this ailment.

There was also significant interaction effect ($p<0.05$) between 1-MCP and storage temperature, 1-MCP and packaging and 1-MCP and cultivar on the changes in fat content throughout the storage period (Table 4).

Total ash

1-MCP treatment recorded significant variation ($p<0.05$) in the ash content of the mango fruit cultivars throughout the storage period (Table 5). Varied ash content was observed through out the storage period. For instance, at the initial stage, the ash content of the mango fruit was 0.93 and 0.98 % for Broken and Dausha respectively. This remained fairly constant at 90 days of storage irrespective of 1-MCP treatments and storage temperature. Similar result was reported by Siddhuraju *et al.,* (1996). The mean ash content reported (0.90 - 0.98 %) is higher than those reported in literature, (0.34 - 0.52 g/100g (Bally, 2006) and also higher than 0.55 - 0.57 % and 0.42 - 0.37 % reported by

Othman and Mbango (2009) and Wenkam and Miller (1965) respectively. The reported values are however; lower than 6.24 %, 6.40 - 9.81 % and 1.35 - 1.70 % reported by Mohammed and Yakubu (2013), Arumugan and Manikandan (2011) and Abdualrahman (2013) respectively. There was no significant increase or decrease in ash because it is the inorganic residue remaining after the water and organic matter has been removed and could not have increased or decreased during storage (Jain *et al.,* 1992, Nielson, 1998).

There was significant interaction effect ($p<0.05$) between 1-MCP and storage temperature, 1-MCP and packaging, 1-MCP and cultivar on the changes in ash content of mango fruit throughout the storage period (Table 5).

Total carbohydrate

The 1-MCP treatment, storage temperature, paperboard packaging and cultivars significantly affected ($p<0.01$) the carbohydrate content of the mango fruit during storage (Table 6). The control recorded the least carbohydrate content (10.57 %) on the first 15 days while the fruit treated with different concentrations of 1-MCP (1000, 3000, 5000 ppb) showed higher carbohydrate content (13.63, 15.77 and 20.11 %). The carbohydrate content increased with increase in 1-MCP concentration and decrease with increasing storage time. This shows that 1-MCP delayed/inhibited ripening and respiration processes that would have led to the consumption of the available carbohydrate. It has been reported that 1-MCP binds irreversibly to ethylene receptors. As a result of this, ripening of 1-MCP treated fruit is delayed until new binding sites are synthesized (Matthesis *et al*., 2003).

Storage temperature significantly affected ($p<0.05$) the carbohydrate content in mango fruit (Table 6). The carbohydrate content decreases with increasing temperature and storage time. Low storage temperature can suppress the respiration rate leading to decrease in the metabolic activities, resulting in the delays of fruit deterioration. Higher temperatures increase metabolic activities in fruit and as such reach their climacteric peak earlier than those kept at lower temperatures. Lower storage temperatures favour the efficacy of 1-MCP and enhance shelf life. The findings in this study are in line with Zaharah and Singh (2011).

Paperboard packaging has a significant difference ($p<0.05$) on the carbohydrate content of the two mango cultivars (Table 6) throughout the storage period. Packaged fruit recorded higher carbohydrate content compared to the unpackaged mango fruits. The result shows that PB packaging delayed the ripening period of the mango fruits. This may be as a result of the high relative humidity and modified atmosphere created in the packages. The role of modified atmosphere packaging is primarily to reduce respiration rate of fruit and vegetables. Reduced respiration also retards softening and slows down various compositional changes such as carbohydrate, which are associated with ripening (Alye, 2005, Zagory and Kedar, 1998). The observed decreased in carbohydrate content of fruit stored without packaging may indicate higher respiration rates and ethylene production because of the exposure to oxygen which favours starch hydrolysis. Higher respiration rate results to fast ripening rate and then postharvest quality deterioration with onset of senescence (Brady, 1987)

In most of the storage periods, significant differences ($p<0.01$) were observed with regard to changes in carbohydrate content between the two mango cultivars. Dausha retained more carbohydrate (20.13 %) than Broken (17.31 %) at the same storage period. The observed difference in the response of carbohydrate to these variables among the mango cultivars could be due to responses in 1-MCP as affected by species,

varietal, genetic and physical characteristics between them such as skin thickness. However, the carbohydrate content decreases with increasing storage period in both varieties but faster in Broken mangoes. The initial carbohydrate content of Broken and Dausha was 19.34 and 20.37 % respectively. These reported values are higher than those found in literature (16.20 - 17.18 %) (Bally, 2006).This may be due to the difference in genetic and maturity stage during harvest. According to Kudachikar *et al*., (2001), mangoes have relatively high carbohydrate content at an unripe stage. However, the carbohydrate content reported for day 15 and 30 in this study compete favourably with the literature values reported. This may be because during this time the fruit ripened to edible stage and carbohydrate was hydrolyzed to simple sugars (sucrose, fructose and glucose) when the effects of 1-MCP were reducing with storage. Also, the carbohydrate content reported in this study for Broken and Dausha is in line with the findings of Ubwa *et al.,* (2014) for Hindi, Julie and local mangoes grown in Benue State. It has also been reported that changes in carbohydrate contents are prominent chemical transformation occurring during the ripening of climacteric fruit such as mango with a decrease in starch and an increase in sugar content occurring during ripening (Doreyappy-Gowda and Huddar, 2001). The main function of carbohydrate is to provide the body with energy. That means Broken and Dausha when consumed may serve as an alternative source of energy for the body.

Significant interaction effect ($p<0.05$) was seen between 1-MCP concentration and storage temperature, 1-MCP concentration and packaging, 1-MCP concentration and cultivar on carbohydrate content of Broken and Dausha days 45, 60 and 90 indicating that these factors are dependent on each other and carbohydrate is concentration-dependent.

CONCLUSION

The 1-MCP concentration, packaging material, storage temperature and time exhibited significant effect ($p<0.05$) on the postharvest proximate composition of the two mango cultivars, Broken and Dausha. The results showed high retention of moisture, crude protein, crude fibre, crude fat, total ash and total carbohydrate contents in the 1-MCP treated and packaged mango samples. Better quality attributes and longevity was observed in Dausha mango samples. The untreated and unpackaged had greater postharvest losses and shorter storage life of only 15 days. The optimum 1-MCP concentration observed for the preservation of Broken and Dausha was 5000 ppb while the optimum storage temperature was 11 ^{o}C. Dausha stored for more than 90 days while Broken stored for 75 days. The results of the study show that 1-MCP alone or in combination with other factors could preserve the nutritional composition of these mangoes and extend their shelf life when stored at controlled temperatures.

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