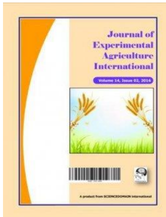

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Effect of 1-Methylcyclopropene (1-MCP) Concentrations on the Physical Quality Characteristics of Two Varieties of Plantain Stored under Three Ripening Stages

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Plantain is an important fruit crop in the diet of local populations with an important growing international market but due to its high postharvest losses. This experiment was set up to assess the effect of 1-MCP and packaging materials on the physical properties of the two varieties of plantain ("Apem" and "Apentu"). A **2×3×3** factorial experiment was used for the plantain fruits physical quality determination at the laboratory under ambient condition. Weight Loss, Moisture Content, Fruit Firmness, Pulp firmness, Shelf Life that were investigated were significantly different ($P<0.01$). From the results, untreated fruits had the highest mean physiological weight loss of 10.33% to 5.38%. "Apem" with 1-MCP (2ppm) had highest mean fruit firmness of 88.50N as compared to untreated fruit which had the lowest mean of 63.83N. For pulp firmness, "Apem" treated with 1-MCP (2ppm) had the highest mean of 76.83N."Apem" treated with 1-MCP (2 ppm)

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kept in non –perforated polyethylene bag (NP) recorded the highest shelf life period of 36.75days (37days) whereas “Apentu” treated with 1-MCP (2ppm) kept in non-perforated polyethylene bag (**NP)** had shelf life of 33.00days (33days). Hence, the interaction between fruits, 1-MCP and Packaging could extend shelf life of plantain fruits.

Keywords: Ethylene, metabolism, respiration, degradation, chlorophyll and pulp.

1. INTRODUCTION

According to IITA [1], Musa (Plantain and Banana) is the first fruit crop produced throughout the world and constitutes an important staple food in many developing countries, especially in Africa. IITA [2] indicated that, in sub-Saharan Africa, plantain and banana offers 25% of carbohydrates and 10% daily intake of calorie for more than seventy million people in the continent. Frison and Sharrock [3] reported that, plantain and banana constitutes the world’s second biggest fruit crop with annual production of 129,906,098m/t. In addition, in the rural economy, plantain is part of the non-traditional sector where it is suitable for shading cocoa seedling. It also forms an important component in human diets. Plantain is placed third after yam and cassava as reported by FAO [4] and contributes Agricultural Gross Domestic Product of about 13.1%. Socioeconomically, plantain cultivation plays an important role by creating jobs and providing food security in Ghana. It again provides revenue to a number of people and raw materials to industries in Ghana who are into value addition business.

Zewter et al. [5] reported that plantain fruits comparatively have higher rate of respiration than banana and extremely perishable. Preserving plantain fruits in the green state is difficult. According to Chia et al. [6] a lot of plantain fruits spoil in the hot weather within which it is produced and distributed. At ambient temperature, plantains averagely have market life of 1-10 days, compared to several weeks for yam. Hence, Fellows [7] indicated that plantain accounts 35 to 100% of post-harvest losses. Due to such inherent characteristics, various handling and marketing technologies (storage, transportation, packaging, etc.) are commercially used to keep quality and prolong its shelf life. Due to the climacteric behaviour of plantain, which produces ethylene during ripening, Saltveit [8] reported that plant hormone ethylene impacts on lignification, abscission, decay, sprouting, chlorophyll loss, senescence and ripening, discolouration, softening, physiological and stimulation of defence systems which are broad range of physiological processes in horticultural crops.

To block the response of basic level of ethylene in plantain fruits and to delay natural ripening procedure significantly, some chemicals have been identified among available methods [9,10]. For instance, [11] as well as Watkins [12] reported that chemical control of ethylene biosynthesis by aminoethoxy vinyl glycine (AVG) and suppression of its action by 1-MCP (1-methylcyclopropene) have become vital tools for the horticulture industry as they look to keep quality of produce after harvest. Scientific reports available indicate advantages of using 1-methylclopropene in postharvest of vegetables and fruits leading to delay in ripening or senescence processes. In 1999 in the USA, among horticultural practice, 1-methylcyclopropene was introduced. Used as the formulation (SmartFresh) to delay ripening in vegetables and fruits.1-methylcyclopropene is cyclopropene which is part of a class of compounds. Blankenship and Dole [13], discovered that cyclopropenes suppress ethylene perception by competitively binding to ethylene receptors constitute a major discovery in controlling ethylene responses of horticultural products. Blankenship and Dole [13] as well as Watkins [14] emphasised that for human 1-methylcyclopropene is safe and quickly diffuses after treatment from plant tissue. In achieving that, Sauri-Duch et al. [15] indicated that 1-MCP has effective results in retarding ripening, prolonging shelf life and reducing postharvest loses in a broad variety of climacteric fruits including papaya, avocado, pear, plum, apple and sapodilla. However, there is dearth of scientific information on the effect of 1 MCP on the physical properties and shelf life of plantain. Thus, to extend the shelf life of climacteric fruits, it is important to retard the ripening process of fresh fruits to suppress the process of ethylene gas as stated by Ponce et al. [16] and Watkins et al. [17]. The objective of this study was to determine the effect of different concentrations of ethylene action blocker 1-Methylcyclopropene (1-MCP) on physical properties of two varieties of plantain.

2. MATERIALS AND METHODS

2.1 Experimental Location

The experiment was carried out at Kwame Nkrumah University of Science and Technology-Department of Horticulture Laboratory-Kumasi in the Ashanti Region of Ghana. KNUST is located along the Kumasi-Accra main road about 13 km away from the regional capital Kumasi. It lies on longitude 060 41’5.67” N and latitude 01 0 34’13.87” W.

2.2 Plant Materials (Source of Materials)

Three matured bunches of “Apem” and seven matured bunches of “Apentu” plantains were harvested early morning from a farm at ‘Pipie’ a community in the Bosomtwe District- Ashanti Region. These are the two most commonly cultivated and utilised varieties of plantain belong to the French-type (“Apem”) and False horn-type (“Apentu”) subgroup. According to Akter et al. [18], the fruits of the two have different characteristics and therefore may respond differently to the application of the treatments. The important maturity characteristics used for the selection are as follows the angularness of the cross section of the fruit, finger diameter or length, firmness of the fruits and blackening of the apex of the fruits i.e. fruits are physiologically matured after the emergence of the bud, when the apex of the fruits has obviously blackened.

2.3 Sample (Plant Materials) Preparation

Fruit that were harvested shows ripening signs and the fingers changed to circular but fruits that exhibit yellowing were rejected and not used in the experiment. Harvesting was done in the morning between **7:30-10:30 am** with extra care to avoid mechanical injury to the fruit. Harvested fruits were de-handed and arranged in a paper box lined with dry plantain leaves to provide cushioning and transported to the laboratory by vehicle. Fruits were transported in the morning earlier to ward off light and heat damage. Plantain bunch was de-handed with a knife and separated into individual fingers and similar size rounded fruits were selected. Fruits were selected as samples with no serious defects such as cuts, bruises, deep wounds or insect damage. The selected fruits were washed with running water from a tap to remove latex. The fruits were then graded by size and colour and fruits with defects were rejected. Then unblemished uniform fruits were cleaned using a wet cloth to get rid of dirt particles on the surface of fruits.

2.4 Preparation 1-MCP Concentrations

1-MCP containing **3.3%** 1-MCP active ingredient was obtained from QingDao LuNuo Bio-Technology Co., Ltd., China. 1-MCP doses of 0.00 ppm,1.00 ppm and 2.00 ppm were diluted in 100ml distilled water, an electrical conductivity-(E.C) meter (Model:TDS-3) was dip into the solution to measure the accurate (parts per million) ppm concentration in the solution. Mixing of the solutions was carried out in volumetric glass beakers and covered. After proper shaking of the solution, the beakers was opened and placed at the center of the respective chambers where the fruits was kept. A small portable fan was installed within each of the treatment chambers for evenly distribution of 1-MCP within the respective chambers. Fruits were air dried after taken from the treatment chambers for 24 hours of exposure to 1-MCP. Fruits used as control were kept under the same condition without 1-MCP treatment. In each type, 1-MCP treated fruits were put into two packaging methods; perforated, non-perforated as well as one left without packaging as control and monitored.

2.5 Experimental Design and Treatments

A three-way factorial experiment **(2×3×3)** arranged in Completely Randomized Design (CRD) with three replications were used. Factor one (1) was made up of two varieties of plantain (French-type (“Apem”) False horn-type (“Apentu”), factor two (2) made up of three levels of 1-MCP concentration (0 ppm, 1 ppm, 2 ppm) and factor three (3) made up of three forms of the packaging materials i.e No Packaging Material–**NoP**, Non-Perforated Polyethylene (Ziplock bag)- **NP**, and Perforated Polyethylene (Ziplock bag)-**PP** were used. There were four fingers per treatment for non-destructive analysis and four fingers for the destructive analysis. Fifty transparent (Ziplock) polyethylene bags of size 390 by 290 mm and thickness 0.083 mm was bought at Adum-Kumasi for the treatments. Twenty-four perforations were made using punch two holes paper perforator (Model: E50) in 18 of the polyethylene (Ziplock) bags. After the treated fruits had dried 8 clusters of “Apem” and 8 clusters of “Apentu” were placed in the perforated polyethylene (Ziplock) bags. The same thing was done for the non-perforated polyethylene (Ziplock) bags. The remaining 18 clusters were submitted to the same arrangements but the fruits were not put in polyethylene (Ziplock) bags serving as the control treatment.

2.6 Parameters Studied

2.6.1 Determination of daily room temperature and relative humidity values

A data logger (Tinytag Talk 2 by Gemini data loggers, UK.) was used to record daily temperatures. The device also recorded daily humidity values during the storage period.

2.6.2 Physiological weight loss-PWL

Physiological weight loss of fruits was determine throughout the experimental period, from the experimental unit containing four samples were weighed every three days using electronic balance. The cumulative weight loss was expressed in percentage with respect to different treatments [19]. Weight losses were calculated as percentage of the initial weight.

Weight loss (%) =
$$\frac{Initial\,Weight-W1(g)-Final\,Weight-W2(g)}{Final\,Weight-W2(g)}100$$

2.6.3 Pulp moisture content (%)

Moisture content of plantain was determined for the period of storage. Two grams (2 g) of the pulp was weighed using analytical scale (AAA 100LE).The weighed pulp was placed in Wagtech electric oven and dried at 105°C for 24hrs. The dried pulp was allowed to cool and reweighed after putting into the desiccators.

Pulp Moisture content calculated as
$$:\frac{\boldsymbol{W2-W3}}{\boldsymbol{W2-W1}}\times \mathbf{100}$$

Where,

Initial weight of empty dish=W1
Weight of dish +undried pulp=W2
Weight of dish + dried pulp =W3

2.6.4 Changes in fruit firmness

A digital Durometer (Model: LX-A, C, D) was used to measure the fruit firmness of each sample. The determination of firmness of a fruit by means of a C type Shore Durometer. The firmness was taken along the ripening stages. The principle is based on the pressure necessary to push the plunger of the Durometer into the plantain fruit. The Durometer was zeroed and the plunger head placed against the fruit along four sides. Steady downward pressure was applied until a steady reading was observed. The plunger was removed and the reading on the Durometer was recorded.

2.6.5 Shelf-life

The plantain fruit shelf life was calculated by counting the days required for them to reach the last ripening stage, just up to the stage they are still acceptable for market. The fruit shelf life was determined at the completely yellow ripened stage. Changing of the plantain peel colour to yellow is an indication for plantain ripening. In the banana colour chart it is represented by stage **6** (**all yellow**), all the same stage seven indicates the end of the shelf life of the fruits.

2.7 Data Collection and Statistical Analysis

The data collected and the laboratory work was statistically analysed using Statistix 10.0. The laboratory data was submitted to (ANOVA) i.e. Analysis of variance. Tukey’s Honestly Significant Difference (HSD) at 0.01 was used to separate the treatment means.

3. RESULTS

From Table 1, Apem had the highest number of hands and fingers than Apentu while Apentu had the highest bunch weight, length of figures, finger weight and firmness.

3.1 Physiological Weight Loss (%)

Fig. 1 shows the effect of varieties of plantain on the cumulative weight loss stored under ambient environment. From the above trend,”Apem” and “Apentu” at the first day recorded weight loss of 2.16% and 1.79% respectively. At the end of the 10days “Apem” recorded weight loss of 12.13 % while “Apentu” recorded weight loss of 13.42% were significantly different ($P < 0.01$).

3.2 Effect of Different Concentrations on Physiological Weight loss (%)

Fig. 2 shows the effect of different concentrations of 1-MCP on the cumulative weight loss stored under ambient condition. At day one, weight loss values of 3.70%, 1.65%, and 1.01% was respectively recorded for 1-MCP (0ppm), 1-MCP

(1ppm) and 1-MCP (2 ppm). The weight loss values, however, increased. At day 13, 1-MCP (1ppm) and 1-MCP (2 ppm) recorded weight loss of 16.23% and 17.80% respectively. 1-MCP (1ppm) and 1-MCP (2 ppm) recorded weight loss of 22.40% and 29.67% at end of day 25. The concentrations were significantly different (P<0.01) at day 25.

Table 1. Physical parameters were initially taken as benchmark measurements at day zero (before 1-MCP treatment of fruits)

Parameter Record	French type-'Apem'	False horn-'Apentu'
Av. Bunch wt.**(kg)**	**18**	**40**
Av. Number of hands/bunch	**10**	**7**
Av. Number of fingers/hand	**15**	**7**
Av. Length of fingers**(cm)**	**26**	**27**
Av. Initial finger weight	**162**	**303**
Av. Initial weight of fruits(**4finger**) kept for P.W.L analysis **(g)**	**646**	**1,212**
Firmness(**N**)	**65**	**66**

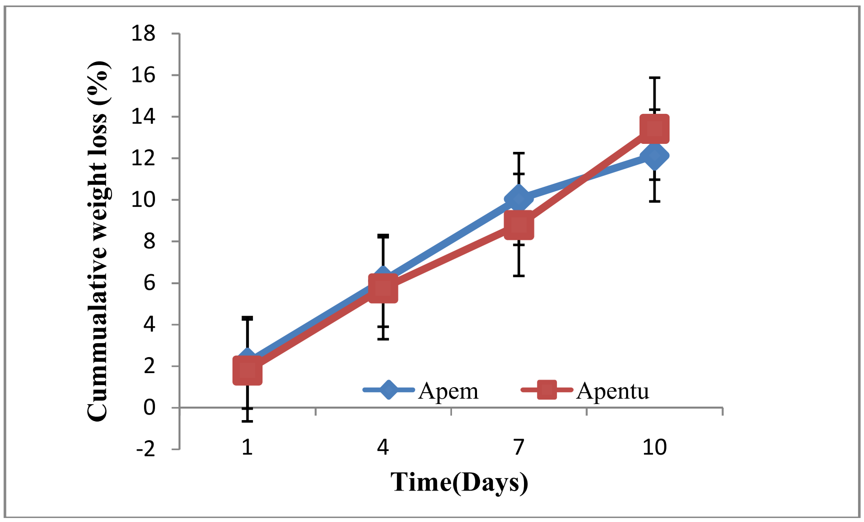

Fig. 1. Effect of Varieties of Plantain on Physiological Weight loss (%)

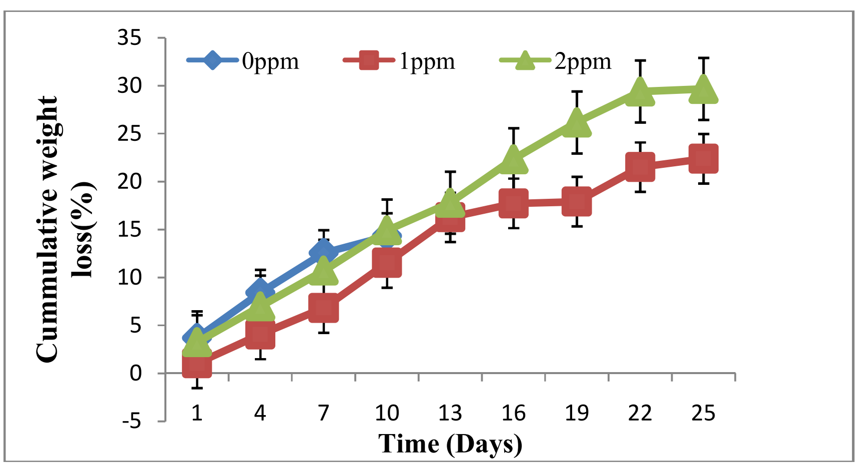

Fig. 2. Effect of different concentrations on physiological weight loss (%)

Fig. 3 shows the effect of different packaging on the cumulative weight loss stored under ambient condition. At day one, weight loss values of 3.05%, 1.44%, and 1.44% was respectively recorded for no- polyethylene (**NoP),** Non - perforated polyethylene (**NP**), Perforated polyethylene (**PP**). Values of weight loss, however, increased. At day 13, Non-Perforated polyethylene (**NP**) and Perforated polyethylene (**PP**) recorded weight loss of 12.50% and 11.16 % respectively. Non-Perforated polyethylene (**NP**) and Perforated polyethylene (**PP**) recorded weight loss of 16.72% and 17.22%.The packaging were not significantly different (P<0.01) at end of day 19.

3.3 Moisture Content (%)

As summarised in Table 2, the effects 1-MCP concentration and packaging on the two varieties of plantain on moisture content were not significantly different (P < 0.01) at ripening stage one. However, significant differences were seen at ripening stage three and six. The highest percentage of 63.50% in moisture content was recorded at ripening stage six for “Apem” treated with 1-MCP (2ppm) kept in perforated polyethylene bag (PP), while in “Apentu” the highest recorded was 67.17% without 1-MCP (0ppm) kept in non-perforated polyethylene bag (NP).

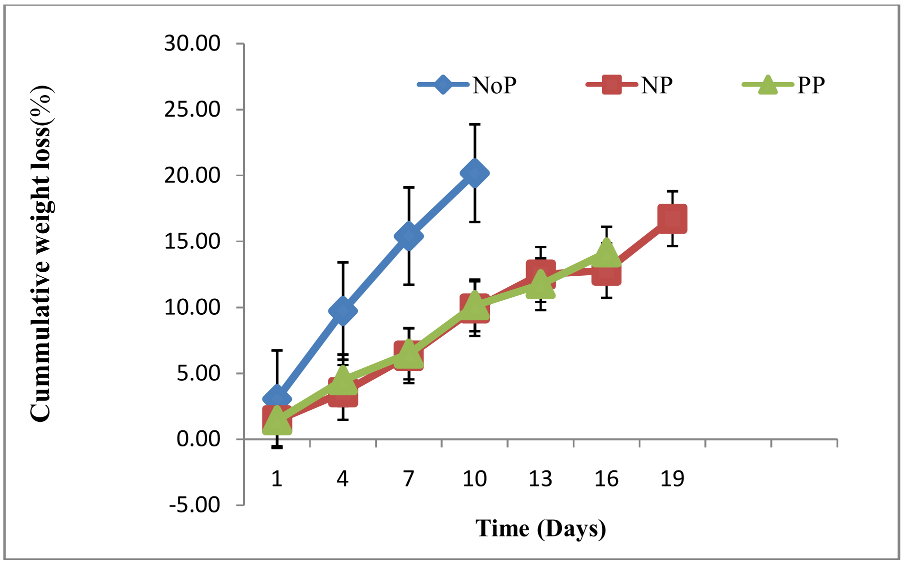

Fig. 3. Effect of packaging on physiological weight loss (%)

Table 2. Shows the effect of 1-MCP and packaging on moisture content (%) on the two type of plantain stored under ambient condition

Treatments	**RS1**		**RS3**		**RS6**	
Package 1-MCP	**“Apem”**	**“Apentu”**	**“Apem”**	**“Apentu”**	**“Apem”**	**“Apentu”**
0ppm NoP	58.500a	63.500a	58.000bcd	57.667cd	59.000fg	65.167abc
NP	58.667a	60.500a	65.333ab	66.000a	62.333cdef	67.167ab
PP	58.000a	60.500a	56.167d	61.167abcd	63.500bcd	65.333abc
1ppm NoP	55.000a	59.333a	56.667cd	64.167abc	59.167efg	63.167abc
NP	57.933a	60.000a	62.500abcd	58.667abcd	62.167cded	62.333cdef
PP	55.000a	57.500a	58.000bcd	62.667abcd	57.167g	68.000a
2ppm NoP	63.000a	68.333a	56.333d	56.000d	59.167efg	62.167cdef
NP	58.500a	61.500a	62.500abcd	62.000abcd	60.500defg	61.333cdefg
PP	57.000a	60.667a	60.500abcd	63.500abcd	63.500bcd	62.833cdef
HSD (1%)	**16.295**	**16.295**	**7.6092**	**7.6092**	**4.1344**	**4.1344**
C.V	**7.62**	**7.62**	**3.51**	**3.51**	**1.84**	**1.84**

**Means followed by different letters are significantly different at P<0.01 (Tukey’s Test)*
***Key: RS**=Ripening Stages. **NoP**= No- Polyethylene, PP-Perforated Polyethylene, NP-Non-Perforated Polyethylene **1-MCP** = 1-Methylcyclopropene.*

3.4 Fruit Firmness (N)

The response of 1-MCP concentration and packaging on the two varieties of plantain on Fruit Firmness were significantly different (P<0.01). As summarised in the Table 3, "Apentu" fruits untreated with 1-MCP (0 ppm) kept in perforated polyethylene bag (PP) recorded fruit firmness of 63.83 N which is lower than 65.33N value recorded in "Apem" fruit untreated with 1-MCP (0ppm) with no polyethylene bag (NoP) at ripening stage one. But then the highest firmness value of 88.50N was recorded in "Apem" treated with 1-MCP (2 ppm) kept in perforated polyethylene kept bag (PP).

3.5 Pulp Firmness

As summarised in the Table 4, the effects 1-MCP concentration and packaging on the two varieties of plantain on pulp firmness were significantly different (P < 0.01). As summarised in the table above. "Apentu" fruits untreated with 1-MCP (0 ppm) with no polyethylene bag (NoP) recorded low pulp firmness value of 0.00 N while "Apem" fruit untreated with 1-MCP (0 ppm) with perforated polyethylene bag (PP) at ripening a

Table 3. Shows the Effect of 1-MCP and Packaging on fruit firmness (N) on the two type of plantain stored under ambient condition

Treatments	RS1		RS3		RS6	
Package 1-MCP	"Apem"	"Apentu"	"Apem"	"Apentu"	"Apem"	"Apentu"
0ppm NoP	65.333bc	72.667abc	64.000bcde	71.000abcd	25.333i	31.833ghi
NP	77.917abc	81.167abc	43.000f	60.767de	43.333fgh	43.667fgh
PP	77.583abc	63.833c	76.333abcde	59.333ef	23.333i	28.333hi
1ppm NoP	76.833abc	71.667abc	63.500bcde	71.667abcde	60.833abcd	70.167a
NP	87.167a	84.667ab	62.000cde	74.167abcde	50.000def	69.833abc
PP	84.750ab	80.667abc	82.000a	75.667abcde	45.667fgh	60.167cdef
2ppm NoP	79.667abc	75.667abc	71.667abc	73.500abcde	68.833abcd	69.100ab
NP	82.917abc	84.167ab	82.833a	80.167ab	74.833ab	63.833abcd
PP	88.500a	83.267abc	85.333a	79.333abc	57.500cdef	61.000bcde
HSD (1%)	**20.009**	**20.009**	**3.9717**	**3.9717**	**16.918**	**16.918**
C.V	**7.08**	**7.08**	**6.80**	**6.80**	**8.86**	**8.86**

**Means followed by different letters are significantly different at P<0.01 (Tukey's Test)*
***Key: RS=**Ripening Stages. **NoP=** No- Polyethylene, PP-Perforated Polyethylene, NP-Non-Perforated Polyethylene **1-MCP** = 1-Methylcyclopropene.*

Table 4. Shows the Effect of 1-MCP and Packaging on Pulp Firmness (N) on the two type of plantain stored under ambient condition

Treatments	RS1		RS3		RS6	
Package 1-MCP	"Apem"	"Apentu"	"Apem"	"Apentu"	"Apem"	"Apentu"
0ppm NoP	32.667c	42.000ab	12.667d	22.833cd	3.8333d	0.0000d
NP	56.850abc	62.600ab	21.167cd	11.333d	2.5000d	0.0000d
PP	53.183abc	55.667abc	21.000cd	9.667d	1.0000d	0.5333d
1ppm NoP	67.833ab	60.167ab	44.000ab	49.333ab	43.833abc	48.667ab
NP	58.833abc	55.833abc	17.833cd	44.167bc	5.6667d	41.667bc
PP	57.900abc	72.333a	57.833a	53.333ab	5.667d	7.6667d
2ppm NoP	65.333ab	66.167ab	52.833ab	55.500a	47.000abc	54.000ab
NP	67.500ab	72.333a	61.000a	51.500ab	34.833c	15.667d
PP	76.833a	66.167ab	59.167a	58.833a	14.333d	7.667d
HSD (1%)	**27.336**	**27.336**	**19.364**	**19.364**	**17.466**	**17.466**
C.V	**12.73**	**12.73**	**14.00**	**14.00**	**24.938**	**24.938**

Means followed by different letters are significantly different at P <0.01 (Tukey's Test)
***Key: RS=**Ripening Stages. **NoP=** No- Polyethylene, PP-Perforated Polyethylene, NP-Non-Perforated Polyethylene **1-MCP** = 1-Methylcyclopropene.*

Table 5. Show the effect of 1-MCP and Packaging on the Shelf-life of two type of plantain stored under ambient condition

Treatments Package	SL in DAS	
1-MCP	"APEM"	"APENTU"
0ppm NoP	**11.250i**	**11.000i**
NP	21.500fg	22.000f
PP	25.750cde	23.500ef
1ppm NoP	15.000hi	11.500i
NP	26.250cde	27.500bcd
PP	26.000cde	24.000ef
2ppm NoP	14.250hi	17.250gh
NP	**36.750a**	**33.000ab**
PP	29.000bc	24.500ef
HSD (1%)	**4.6296**	**4.6296**
C.V	**12.93**	**12.93**

Means followed by different letters are significantly different at P <0.01 (Tukey's Test)
***Key: RS=**Ripening Stages. **NoP=** No- Polyethylene, PP-Perforated Polyethylene, NP-Non-Perforated Polyethylene **1-MCP** = 1-Methylcyclopropene.*

stage six recorded firmness of 1.00N. But then, high pulp firmness value of 76.83N was recorded in "Apem" treated with 1-MCP (2 ppm) kept in perforated polyethylene bag (PP) as compared to the highest of 72.33N in "Apentu" treated with 1-MCP (1 ppm) kept in perforated polyethylene bag (PP).

3.6 Shelf Life

As summarised in the Table 5, the effects 1-MCP concentration and packaging on the two varieties of plantain on Shelf life were significantly different (P < 0.01). "Apem" treated with 1-MCP (2 ppm) kept in non –perforated polyethylene bag (NP) recorded the highest shelf life period of 36.75 (37) days compared to "Apem" without 1-MCP (0.00 ppm) with no- polyethylene bag (NoP) of 11.25 (11) days. However, in the case of "Apentu treated with 1-MCP (2 ppm) kept in non-perforated polyethylene bag (NP) also prolong the shelf life to 33.00 days as compared to "Apentu" without 1-MCP (0ppm) with no-polyethylene bag (NoP).

4. DISCUSSION

4.1 Weight Loss of Plantains

Results showed that the highest percentage weight loss of 10.33% was recorded in 1-MCP untreated "Apem" fruits with no polyethylene bag (NoP), as compared to highest mean of 5.38% in 1-MCP untreated "Apentu" fruits kept in non-perforated polyethylene bag (NP). The differences in the mean between the two varieties of plantain might be due to their chemical and natural properties characteristics. "Apem" naturally has smaller fruits with higher surface to volume ratio compared to "Apentu".

The higher surface area to volume ratio may be the reason for "Apem" losing more weight in storage than "Apentu" A lower percent weight loss of 1.85% was recorded in "Apem" fruit treated with 1-MCP (1 ppm) kept in non – perforated polyethylene bag (NP) as compared to 2.32% the lowest mean in Apentu treated with 1-MCP (2 ppm) kept in non-perforated polyethylene bag (NP). The lower weight loss obtained from fruits kept in polyethylene bags without perforation compared to those in perforated ones could be due to removal of ethylene which has a catalytic role in increasing respiration [20] while maintaining relative humidity in the package hence reducing water loss.

The polyethylene bag treatments reduced weight loss significantly compared to the one without polyethylene. Inclusion of 1-Methylcyclopene in fruits packaged in polyethylene further reduced the weight loss. Jeong et al. [21] stated that fruit treated with 1-MCP have lower weight loss than untreated fruit. The polyethylene bag conserved moisture around the fruit since loss of water during storage is one of the main causes of weight loss in fruits [22].

The effect of the 1 -MCP slowed down respiration which leads to reduced weight loss and hence maintaining fruits for longer periods of time [23,24]. This result corresponds with the weight loss value reported by Dharmasenal and Kumari [25] for fruits stored under open ambient condition for the same period. The removal of ethylene and/or inhibition of its effect in the storage environment are fundamental to maintaining postharvest quality of climacteric produce [8]

4.2 Moisture Content (%)

Our results showed that at ripening stage one, among the means there was no significant differences recorded for the moisture content of the two varieties of plantain. However, significant differences were seen at ripening stage three and six. The highest percentage of 63.50% in moisture content was recorded at ripening stage six for "Apem" treated with 1-MCP (2 ppm) kept in perforated polyethylene bag (PP), while in "Apentu" the highest recorded was 67.17% without 1-MCP (0ppm) stored in non-perforated polyethylene bag (NP). Increasing in the membrane permeability following the respiratory climacteric could result in loss of moisture through the peel [26].

4.3 Fruit Firmness (N)

Our results showed that there were significant differences of 1-MCP and packaging materials on the two varieties of plantain. Low values of firmness were recorded in "Apentu" fruits untreated with 1-MCP kept in perforated polyethylene bag (PP) recorded 63.83 N and "Apem" fruit untreated with 1-MCP with no polyethylene bag (NoP) at ripening stage one recorded firmness of 65.33N. But then the highest value of firmness of 88.50N was observed in "Apem" treated with 1-MCP (2 ppm) kept in perforated polyethylene bag (PP). Firmness of two varieties of plantain dropped during the ripening stages; nonetheless, treated fruit softened at a slower pace compared to the untreated fruit. Similar instance of firmness reduction were record in *Hylocereus undatus* fruits stored at 20°C when they reached consuming maturity. Fruits treated with 1-MCP are slower to soften, firmer and slower to change skin colour [27,28]

Likewise, studies by Maalekuu et al. [29] observed strong correlation between fruit firmness, weight loss and general fruit appearance. Surprisingly, Fernández-Trujillo et al. [30] found that 1-MCP (900 nL L −1) may have increased the red pepper fruit susceptibility to shriveling, weight loss, and finger texture. A strong relationship between firmness and weight loss in bell pepper was backed by Lurie et al. [31]. The action of hydrolase enzyme is involved in loss of firmness behaviour, which is induced by ethylene [32]; enzymes such as polygalacturonase (PG), pectin methyl esterase (PME), β-galactosidase and pectate lyase (PL) degrade the polymeric carbon hydrates, especially those of pectic and hemicellulosic substances [33,34] through which the cell walls and the tensile force, which hold the cells together, are weakened [35] and the softening of the dragon fruit may have been accelerated.

The effects of 1-MCP treatment delays softening which is closely associated with ethylene production [36,37]. The components of texture that are affected by 1-MCP have not been adequately investigated but tissue toughness is greater in 1-MCP treated fruit than untreated fruit [38]. Again, [36] reported that fruit kept at high temperatures (20-24º C) have excellent firmness retention.

4.4 Pulp Firmness (N)

The differences were significant ($P < 0.01$) among all treatments during the ripening stages, on the two varieties of plantain handled under ambient condition during the study period. Our results showed that firmness with low values were recorded in "Apentu" fruits untreated with 1-MCP (0 ppm) with no polyethylene bag (NoP) recorded 0.00 N and "Apem" fruit untreated with 1-MCP (0 ppm) kept in perforated polyethylene bag (PP) at ripening stage six recorded firmness of 1.00N. On the one hand, the highest values pulp firmness of 76.83N was recorded in "Apem" treated with 1-MCP (2 ppm) kept in perforated polyethylene bag (PP) as compared to the highest of 72.33N in "Apentu" treated with 1-MCP(1 ppm) kept in perforated polyethylene bag (PP).

4.5 Shelf Life

Observation for the two varieties of plantain shows high significant variation among them. Under ambient condition "Apem" treated with 1-MCP (2 ppm) kept in non–perforated polyethylene bag (NP) recorded the highest shelf life period of 36.75days (37days) compared to "Apem" without 1-MCP (0.00 ppm) with no polyethylene bag (NoP) of 11.25 days (11days). However, in the case of "Apentu" treated with 1-MCP(2ppm) kept in non-perforated polyethylene bag (NP) also prolong the shelf life to 33.00days

(33 days) as compared to "Apentu" without 1-MCP(0 ppm) with no-polyethylene bag (NoP).

The effectiveness of 1 -MCP in combination with polyethylene bag might have effects on the shelf life of both varieties. The explanation for this could be the inhibitory action of ethylene by 1 -MCP [39], reduced ethylene production under modified atmosphere packaging. Osman et al. [40] also reported that, polymeric film packaging has been widely utilised to reduce water loss and to enhance quality of fruit ambient condition while in other treatments either of these causes might have been affected.

5. CONCLUSION

Higher concentration of 1-Methylcyclopropene (2 ppm) resulted in extending shelf-life further while maintaining the physical quality attributes of the two varieties of plantain throughout the ripening stages. This study revealed that untreated fruits had the highest mean physiological weight loss of 10.33% to 5.38%. "Apem" with 1-MCP (2 ppm) had highest mean fruit firmness of 88.50N as compared to untreated fruit which had the lowest mean of 63.83N. For pulp firmness, "Apem" treated with 1-MCP (2 ppm) had highest mean of 76.83N."Apem" treated with 1-MCP (2 ppm) kept in non –perforated polyethylene bag (NP) recorded the highest shelf life period of 36.75 days (37days) whereas "Apentu" treated with 1-MCP (2 ppm) kept in non-perforated polyethylene bag (**NP)** had shelf life of 33.00 days (33 days). Hence, the interaction between fruits, 1-MCP and Packaging could extend shelf life of plantain fruits.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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