EFFECT OF DIFFERENT CONCENTRATIONS OF 1-MCP AND VARIED STORAGE ENVIRONMENTS ON PHYSICAL CHARACTERISTICS AND CONSUMER ACCEPTABILITY OF SOLO PAPAYA (*Carica* papaya L.) FRUITS

ABSTRACT

The nature of papaya fruits is intently connected with their physical characteristics. Changes during aging are critical, yet uncontrolled ripening procedure can prompt fast degradation of quality. Despite the myriads of problems during storage and transportation or distribution, it is imperative to control ripening so as to reduce losses and maximize profit. A 4x2 factorial experiment in a completely randomized design was carried out to determine the effects of applying four concentrations of 1-MCP under two storage conditions on physical characteristics and consumer acceptability of 'Solo' papaya. During ripening, data on various physical characteristics including fruit firmness, cumulative weight loss (%), fruit skin color, shelf life and consumer acceptability were monitored. The 1-MCP treated fruit retained their firmness better than the control (untreated) fruit, regardless of whether they were stored under ambient or cold storage conditions. The percentage of weight loss decreased with increasing 1-MCP concentrations. In general, the 1-MCP treated fruit revealed a slower rate of color change compared to the control. The shelf-life of the papaya fruit treated with 1.5 ppm of 1-MCP and stored under ambient storage condition was extended by approximately 2 days. However, at the same concentration (1.5ppm) of 1-MCP but under cold storage condition, shelf life was extended by approximately 3 days.

Keywords: biosynthesis, climacteric, depolymerization, inhibition, respiratory, and senescence

1. INTRODUCTION

The Solo papaya, *Carica papaya L*., is a member of the small family *Caricaceae*. Papaya also known as pawpaw is a native of tropical America and is now grown in most tropical countries. It is a popular breakfast food, makes excellent fruit salad and dessert. It can also be prepared into jams, purees, juices and is incorporated into various food preparations [1]. The fruit contains high amounts of vitamins A [11-32 mg(100g)] and C [69-71 mg(100g)] and is also considered a laxative.

Papaya is a climacteric fruit and ripens quickly when mature. Although the changes that occur during ripening are imperative for obtaining fruit of good eating quality, uncontrolled ripening process can prompt rapid fruit decay. Thus, it is vital to control the ripening process during storage and distribution so as to keep up natural product quality at the most ideal state until reaching the customer [15].

During ripening, loss of firmness is autocatalytic and very fast, and thus posing the greatest obstruction to the advancement to a broader market. Fruit softening not only influences the palatability but also shelf life, wastage/spoilage, infection by postharvest pathogens, frequency of harvest, transportation, and storage [6]. Fast-ripening associated with softening in fruits such as papaya, mango, banana, citrus, and pineapple may incur postharvest losses that can be as high as 35% ([11]; [12]).

More than 70,000 tons of fruits are sent out from Ghana every year and the principal fruits traded are pineapples, citrus, bananas, and papayas [12]. Unfortunately, these fruits are highly perishable due to ripening which occurs very quickly after harvest, leading to prohibitively narrow time windows for export and sales.

Cold storage of papaya could extend its shelf life but may cause chilling injury which is characterized by black discoloration, rapid loss of firmness, tissue acidification and a decrease in antioxidant content. In addition, cold storage facility is expensive due to high energy cost. Thus, employing alternative means of delaying ripening could be beneficial in delaying fruit decay.

1-Methylcyclopropene (1-MCP) is a compound utilized as inhibitor of ethylene and a synthetic plant growth regulator for many fruits, appearing to be highly effective in delaying fruit ripening and controlling senescence ([7]; [35]). 1-MCP is a gas that hinders the ethylene activity by binding to its receptor on the cell membrane of plant material, greatly reducing the changes associated with ripening and thus extending the postharvest life of fruits and vegetables ([23]; [31]; [32]). This compound is viewed as a very important tool in postharvest innovation, in storage and in the transportation of ethylene sensitive fruits, keeping up quality as if they were freshly harvested ([10]; [29]; [30]).

The compound concentration required to promote inhibition of the ethylene action varies according to the species, cultivar, maturation stage, temperature and exposure time, and the generation of new ethylene receptors on the cell membranes ([33]; [26]).

Hence this research was done for examining the impacts of various 1-MCP concentrations in combination with various storage conditions on physical characteristics and consumer acceptability of 'Solo' papaya.

2. MATERIALS AND METHOD

2.1 EXPERIMENTAL SITE AND DURATION

This experiment was conducted at the Laboratory of the Department of Horticulture in Kwame Nkrumah University of Science and Technology at Kumasi from the month of December 2018 to January 2019. KNUST is situated along the Kumasi-Accra highway about 13 km from Kumasi. It lies on longitude 060 41'5.67" N and latitude 01 034'13.87" W.

2.2 SOURCE OF PAPAYA FRUITS

Papaya 'Solo' fruits was obtained from Saint Osie Farms (Asamankese) in the Eastern region of Ghana. Three hundred fifty fruits of uniform size, color and maturity were harvested. The fruits were transported to the Department of Horticulture laboratory, KNUST in Kumasi in cartons for storage and analysis. Damaged fruits were removed by sorting.

Mature fruits uniform in shape and size without any deformity and apparently showing no sign of diseases were selected. The fruits were washed under running water then placed on a clean bench and allowed to dry.

2.3 APPLICATION OF 1-MCP

Three hundred papaya fruits were divided into four different sets with each set containing seventy-five papaya fruits. 0.15g, 0.1g, 0.05g, and 0g of 1-MCP were dissolved in a beaker containing 10ml of distilled water to form 1.5ppm, 1ppm, 0.5ppm and 0ppm concentrations of 1-MCP. The gas produced was introduced to the fruits by placing the 75 fruits and the beaker with the solution in 4 different high-density polyethylene bags (0.84m^2). An electric fan (100cm^2 with 3 blades) was introduced in the bags to help circulate the 1-MCP gas. The high-density polyethylene bags were sealed for 24 hours after which the bags were opened and the fruits arranged 5 per carton for storage.

2.4 PARAMETERS STUDIED

2.4.1 DAILY ROOM TEMPERATURE AND RELATIVE HUMIDITY DETERMINATION

A data logger (Tinytag Talk 2 by Gemini data loggers, UK) was used to take the temperature and relative humidity readings daily throughout the storage period for both cold and ambient storage environments.

2.4.2 FIRMNESS

The firmness of the fruit was determined using a digital durometer (Model Shore C 0-100HC, Sauter). The durometer was zeroed. The papaya fruits were placed on a horizontal (laboratory bench) surface. The non-destructive test was carried out by pressing the pressure needle stroke of the durometer against the fruit at the middle, stem end and the end of the fruit. The readings were taken, and the average recorded in newton (N).

2.4.3 CUMULATIVE WEIGHT LOSS (%)

Determination of papaya fruits weight loss was carried out daily using an electronic balance (Model: ZPS Series). The initial weight of fruits was recorded and subsequent weight recorded at each observation. The percentage weight losses were calculated as follows;

Weight loss (%) = ((W1 - W2)/ W1) x 100

Where W1 = initial weight, and W2 = final weight.

2.4.4 SHELF-LIFE STUDIES

Shelf life starts just after the fruit is harvested. Studies on shelf life were conducted on the Solo papaya fruits. During this period, fruit quality was monitored visually. Shelf life studies were terminated when the fruits started showing signs of rots or exceeded the last stage on the color chat (Stage 6).

2.4.5 MEASUREMENT OF RATE OF COLOR

Classification of fruits was based visually comparing papaya fruits peel color with standard color chart from the Directorate for Food Safety and Quality Assurance Import-protocols (2015) South Africa.

2.5 EXPERIMENTAL DESIGNS AND LAY OUT

The design for the experiment was a 4X2 factorial in a Completely Randomized Design. The factors involved were, 4 concentrations of 1-MCP (0ppm, 0.5ppm, 1ppm and 1.5ppm) and 2 storage conditions [Ambient (Temperature-26.08 °C, Relative Humidity-82.58 %) and cold storage (Temperature-17.02 °C, Relative Humidity-59.85 %)].

2.6 EVALUATION OF SENSORY CHARACTERISTICS

Sensory characteristics were evaluated for peel and pulp color, firmness, taste, aroma, texture and overall acceptability at the laboratory of the Department of Horticulture, KNUST using 40 untrained panelists. Papaya fruits from the various treatments were assessed using a five-point hedonic scale (1 = Like very much, 2= Like moderately, 3 = Like slightly, 4 = Dislike moderately and 5 = Dislike very much). Average of the scores for each sensory attribute was then calculated.

2.7 DATA ANALYSIS

Data were subjected to analysis of variance (ANOVA) via GenStat 12 edition statistical package and differences among means were analyzed by LSD Post-Hoc comparisons (separated at 1%).

3. RESULTS

3.1 PHYSICAL PARAMETERS

3.1.1 Firmness

Papaya fruits treated with 0.5ppm of 1-MCP and stored under colder condition (17.02 °C and rH of 59.85 %) had the highest firmness (Table 1.), with the latter differing significantly only from fruits that were not treated with 1-MCP (control).

As regards to the 1-MCP treatment applied, it was observed that fruit treated with 0.5ppm had the highest (59.79 N) and the control fruit (0ppm) the lowest firmness (38.40 N).

With respect to storage condition, no significant differences were observed (*P*>.01). The mean firmness values for all 1-MCP treatments combined were 53.22N and 52.66N for ambient and cold storage condition, respectively.

Table 1. Firmness of 1-MCP treated Solo papaya under varied concentrations and storage environments.

Firmness (N)			
	Storage condition		
1-MCP concentration	Ambient (26.08°C, rH 82.58 %)	Cold room (17.02°C, rH 59.85 %)	Mean
0ppm	38.13 B	38.67 B	38.40 B
0.5ppm	59.25 A	60.33 A	59.79 A
1ppm	55.88 A	56.96 A	56.42 A
1.5ppm	58.54 A	55.75 A	57.15 A
Mean	53.22 A	52.66 A	
CV (%) =5.50			
LSD 1-MCP concentration (.01) =4.90			
LSD Storage condition (.01) =3.47			
LSD interaction (0.01) =6.94			

3.1.2 Cumulative Weight Loss (%)

The cumulative percentage weight loss of the 1-MCP treated Solo papaya and its interactions with storage conditions resulted in significant differences (*P*≤.01) in the treatments. The highest cumulative weight loss (1.42%) was recorded in control fruit (0ppm of 1-MCP) stored in cold storage and the least cumulative weight loss was recorded for papaya fruits treated with 1ppm and 1.5ppm of 1-MCP under ambient storage conditions.

As shown in table 2, there were no significant differences (*P* >.01) in mean values between the different 1-MCP treatments. On the other hand, there were significant differences between the means of the two storage conditions (*P* ≤.01). The maximum mean cumulative weight loss was recorded for papaya fruits stored in cold storage (1.35%) and the minimum mean cumulative weight loss as recorded for fruits kept under ambient conditions (1.18%).

Table 2. Cumulative Weight Loss of 1-MCP treated Solo papaya under varied concentrations and storage environments.

Weight loss (%)			
	Storage condition		
1-MCP concentration	Ambient (Temp.-26.08 °C, RH-82.58 %)	Cold room (Temp.-17.02 °C, RH-59.85 %)	Mean
0ppm	1.28 ABC	1.42 A	1.35 A
0.5ppm	1.17 BC	1.36 AB	1.27 A
1ppm	1.14 C	1.29 ABC	1.22 A
1.5ppm	1.14 C	1.33 ABC	1.24 A
Mean	1.18 B	1.35 A	
CV (%) =7.15			
LSD 1-MCP concentration (0.01) = 0.15			
LSD Storage condition (0.01) = 0.11			
LSD interaction (0.01) = 0.22			

3.1.3 Color of Fruit

The color of the Solo papaya fruits as influenced by 1-MCP and the storage condition showed significant differences (*P*≤.01). The color ranged from 2.87 to 5.87. The least color change was observed for fruits treated with 0.5ppm of 1-MCP under ambient storage and the highest was recorded for control fruit (0ppm of 1-MCP) under cold storage condition.

Again, there were significant differences among the means of the color of 1-MCP treated fruits (*P*≤.01). The highest and lowest level of color change was seen for fruits with 0ppm and 0.5ppm of 1-MCP, respectively. Contrary to this trend, the means of the color change with respect to storage conditions showed no significant differences (*P*>.01), with 3.99 and 3.85 recorded for ambient (higher) and cold (lower) storage condition, respectively.

Table 3. Effect of 1-MCP treatment and storage environment on the color change of Solo papaya

Color			
	Storage condition		
1-MCP concentration	Ambient (Temp.26.08 °C, RH82.58 %)	Cold room (Temp.17.02 °C, RH 59.85 %)	Mean
0ppm	5.87 A	5.74 A	5.81 A
0.5ppm	2.87 D	3.13 CD	3.00 C
1ppm	3.69 B	3.34 BCD	3.52 B
1.5ppm	3.52 BC	3.17 BCD	3.35 BC
Mean	3.99 A	3.85 A	
CV (%) =5.70			

LSD 1-MCP concentration (0.01) = 0.38
LSD Storage condition (0.01) = 0.27
LSD interaction (0.01) = 0.53

3.1.4 SHELF LIFE

There were significant differences (*P*≤.01) in the means of the Shelf life interactions of the treatments applied. The highest value was 9.86 days and the least was 7.80 days which were recorded for fruit treated with 0.5ppm 1-MCP stored in cold room and control fruit stored in cold room, respectively. Generally, the interactions had a better effect on shelf life than the individual effects.

The mean values for the individual effects of 1-MCP concentrations and storage environments also showed significant differences (*P*≤.01). 9.20 days and 7.27 days were the maximum and minimum values respectively for the individual effects of 1-MCP concentrations applied. Storage conditions mean shelf-life values also ranged from 7.88 days for ambient storage to 8.87 days for cold storage respectively.

Table 4. Shelf life of 1-MCP treated Solo papaya under ambient and cold room storage environment

SHELF LIFE (DAYS)	
1-MCP concentration	Storage condition

	Ambient (Temp.-26.08 °C, RH-82.58 %)	Cold room (Temp.-17.02 °C, RH-59.85 %)	Mean
0ppm	6.73 D	7.80 CD	7.27 B
0.5ppm	7.93 CD	9.20 AB	8.57 A
1ppm	8.33 BC	8.60 BC	8.47 A
1.5ppm	8.53 BC	9.86 A	9.20 A
Mean	7.88 B	8.87 A	
CV (%) =15.18			
LSD 1-MCP concentration (0.01) = 0.86			
LSD Storage condition (0.01) = 0.61			
LSD interaction (0.01) = 1.22			

3.2 STORAGE ENVIRONMENT

3.2.1 Temperature and Relative Humidity

Table 5. shows the mean temperature and humidity that occurred within the storage environments within which the papaya fruits were stored. There were significant differences ($P \leq .01$) among the mean values for temperature and humidity in the storage environments used. The highest mean temperature (26.08^{o}C) was recorded for ambient storage environment and least mean (17.02 ^{o}C) value for temperature was recorded for cold storage.

The mean relative humidity of ambient and cold room storage environments during the period of storage is shown in Table 5. The average mean Relative Humidity of 82.58% and 59.85% were recorded for ambient and cold room storage environments respectively.

Table 5. Temperature and Humidity of storage periods ambient and cold room storage environment.

	Temperature °C	Relative humidity (%)
Ambient	26.08 A	82.58 A
Cold room	17.02 B	59.85 B
CV (%)	4.16	7.30
LSD (0.01)	0.30	1.74

3.3 SENSORY EVALUATION

The scores of the individual sensory attributes evaluated using the five-point hedonic scale (1 = like much, 2= Like a little, 3 = neither like nor dislike, 4 = dislike a little and 5 = dislike much) are described in this section.

3.3.1 Peel Color

There were significant differences ($P \leq .01$) observed for the interaction effect of the papaya fruits. The highest effect was recorded for fruits treated with 1-MCP at a concentration of 0.5ppm under both cold and ambient storage whiles the lowest value was recorded for 1-MCP treated fruits at a concentration of 1.5ppm in cold storage. Significant differences

(*P*≤.01) with respect to the perceived peel color were also observed in between different 1-MCP treatments – the scores ranged from 2.45 to 2.93. With reference to the storage condition used, there were no significant differences between the treatments.

Table 6. Effect of 1-MCP and storage conditions on consumer perception of peel colour of Solo Papaya fruit.

PEEL COLOUR			
	Storage condition		
1-MCP concentration	Ambient (Temp. 26.08 °C, RH 82.58 %)	Cold room (Temp.-17.02 °C, RH-59.85 %)	Mean
0ppm	2.90 A	2.90 A	2.90 A
0.5ppm	2.93 A	2.93 A	2.93 A
1ppm	2.85 A	2.85 A	2.85 A
1.5ppm	2.46 B	2.44 B	2.45 B
Mean	2.79 A	2.78 A	
CV (%) = 15.98			
LSD 1-MCP concentration (0.01) = 0.18			
LSD Storage condition (0.01) = 0.13			
LSD interaction (0.01) = 0.26			

3.3.2 Pulp Color

As seen in Table 7, the differences in pulp color were significant (*P*>.01) for both the individual effects of the treatments and their interactions. The preferred papaya pulp fruit color was observed in fruit treated with 1.5ppm of 1-MCP and stored under ambient storage (2.61). The least preferred pulp color was revealed in fruits without 1-MCP treatment, stored under cold conditions. With reference to the individual 1-MCP treatments, the maximum value of 2.72 and a minimum value of 2.57 were recorded. For the storage conditions used ambient and cold room storage recorded same mean value of 2.63.

Table 7. Effect of 1-MCP and storage conditions on consumer perception of the pulp color of Solo Papaya.

PULP COLOUR			
	Storage condition		
1-MCP concentration	Ambient (Temp.-26.08 °C, RH-82.58 %)	Cold room (Temp.-17.02 °C, RH-59.85 %)	Mean
0ppm	2.71 A	2.73 A	2.72 A
0.5ppm	2.59 A	2.71 A	2.65 A
1ppm	2.63 A	2.51 A	2.57 A
1.5ppm	2.61 A	2.56 A	2.59 A
Mean	2.63 A	2.63 A	
CV (%) = 18.59			
LSD 1-MCP concentration (0.01) = 0.20			
LSD Storage condition (0.01) = 0.14			
LSD interaction (0.01) = 0.28			

3.3.3 Firmness

Significant differences ($P \leq .01$) were observed in firmness values in the interaction for the concentrations of 1-MCP applied and the storage conditions. The firmest fruits with respect to the interaction were fruits treated with 1.5ppm of 1-MCP stored under ambient storage condition and the fruits with the lowest firmness were the control fruits (0ppm) stored under ambient conditions.

The individual effect of the concentrations of 1-MCP was also significantly different ($P \leq .01$) with respect to their effect on the firmness of Solo papaya fruit. The range of values were from 3.20 to 2.23. However, no significant difference was observed for the treatment means of the storage conditions used. The maximum value was 2.57 and the minimum value was 2.51.

Table 8. Effect of 1-MCP and storage conditions on consumer perception of the Firmness of Solo Papaya.

FIRMNESS			
	Storage condition		
1-MCP concentration	Ambient (Temp.-26.08 °C, RH-82.58 %)	Cold room (Temp.-17.02 °C, RH-59.85 %)	Mean
0ppm	3.24 A	3.15 A	3.20 A
0.5ppm	2.37 B	2.29 B	2.33 B
1ppm	2.46 B	2.34 B	2.40 B
1.5ppm	2.20 B	2.27 B	2.23 B
Mean	2.57 A	2.51 A	
CV (%) = 19.26			
LSD 1-MCP concentration (0.01) = 0.20			
LSD Storage condition (0.01) = 0.14			
LSD interaction (0.01) = 0.28			

3.3.4 Taste

The taste showed significant difference ($P \leq .01$) with respect to the interactive effect between 1-MCP concentrations and storage environment with values ranging from 2.27 to 2.73. Similarly, the individual effect of 1-MCP also showed significant difference among the concentrations applied. On the other hand, storage condition showed no significant difference ($P \leq .01$) with respect to taste of fruits stored under ambient and cold storage conditions, as shown in Table 9.

Table 9. Effect of 1-MCP and storage conditions on consumer perception of the taste of Solo Papaya.

TASTE			
	Storage condition		
1-MCP concentration	Ambient (Temp.-26.08 °C, RH-82.58 %)	Cold room (Temp.-17.02 °C, RH-59.85 %)	Mean
0ppm	2.61 AB	2.68 AB	2.65 AB
0.5ppm	2.44 BC	2.27 C	2.35 C

1ppm	2.49 ABC	2.51 ABC	2.50 BC
1.5ppm	2.73 A	2.68 AB	2.71 A
Mean	2.57 A	2.54 A	
CV (%) = 19.62			
LSD 1-MCP concentration (0.01) = 0.20			
LSD Storage condition (0.01) = 0.14			
LSD interaction (0.01) = 0.29			

3.3.5 Aroma

Interactively, the aroma differed significantly ($P \le .01$) with respect to 1-MCP concentrations and storage conditions. The values recorded ranged from 2.88 being the highest to 2.51 being the lowest, recorded under 0ppm-coldrom and 0.5ppm ambient and cold storage respectively.

The individual effect for papaya fruits stored under ambient and cold storage recorded no significant difference ($P > .01$) with respect to the aroma. However, 1-MCP treated fruits showed significant differences ($P \le .01$) among the treatment concentrations used, the values in this regard ranged from 2.78 to 2.56.

Table 10. Effect of 1-MCP and storage conditions on consumer perception of the aroma of Solo Papaya.

AROMA			
	Storage condition		
1-MCP concentration	Ambient (Temp.-26.08 °C, RH-82.58 %)	Cold room (Temp.-17.02 °C, RH-59.85 %)	Mean
0ppm	2.68 AB	2.88 A	2.78 A
0.5ppm	2.51 B	2.51 B	2.74 AB
1ppm	2.56 B	2.56 B	2.56 BC
1.5ppm	2.76 AB	2.73 AB	2.74 AB
Mean	2.63 A	2.67 A	
CV (%) = 18.10			
LSD 1-MCP concentration (0.01) = 0.19			
LSD Storage condition (0.01) = 0.14			
LSD interaction (0.01) = 0.27			

3.3.6 Texture

There was significant difference ($P \le .01$) in the interactions with regards to 1-MCP concentration and storage condition used. With regarded to the five-point hedonic scale, the range of values recorded were 2.15 to 3.29. As recorded in Table 11, the individual effects of 1-MCP concentrations showed significant differences ($P \le .01$) whiles that of storage conditions did not show and significant differences($P > .01$) among their treatment mean values. Their mean values ranges were 3.29 to 2.18 and 2.49 to 2.58 respectively.

Table 11. Effect of 1-MCP and storage conditions on consumer perception of the texture of Solo Papaya.

TEXTURE

1-MCP concentration	Storage condition Ambient (Temp.-26.08 °C, RH-82.58 %)	Cold room (Temp.-17.02 °C, RH-59.85 %)	Mean
0ppm	3.29 A	3.29 A	3.29 A
0.5ppm	2.46 B	2.17 B	2.32 B
1ppm	2.34 B	2.37 B	2.35 B
1.5ppm	2.22 B	2.15 B	2.18 B
Mean	2.58 A	2.49 A	
CV (%) = 24.53			
LSD 1-MCP concentration (0.01) = 0.25			
LSD Storage condition (0.01) = 0.18			
LSD interaction (0.01) = 0.36			

<u>3.3.7 Overall Acceptance</u>

With respect to the overall acceptability, papaya fruits in both ambient and cold storage conditions showed no significant difference in their mean values (*P*>.01). Papaya fruits treated with 1-MCP irrespective of the storage condition were preferred to the untreated fruit. However, significant differences (*P*≤.01) were observed among the interactive effect of the 1-MCP concentrations and storage conditions used. The least preferred fruits were treated with 0ppm of 1-MCP and stored ambient storage. The mostly preferred fruits were treated with 1.5ppm of 1-MCP and stored ambient storage as shown in Table 12.

Table 12. Effect of 1-MCP and storage conditions on the overall acceptance of Solo Papaya by consumers.

OVERALL ACCEPTANCE			
1-MCP concentration	Storage condition Ambient (Temp.-26.08 °C, RH-82.58 %)	Cold room (Temp.-17.02 °C, RH-59.85 %)	Mean
0ppm	3.15 A	3.10 A	3.12 A
0.5ppm	2.37 B	2.32 B	2.34 B
1ppm	2.27 B	2.22 B	2.24 B
1.5ppm	2.17 B	2.20 B	2.18 B
Mean	2.49 A	2.46 A	
CV (%) = 20.78			
LSD 1-MCP concentration (0.01) = 0.21			
LSD Storage condition (0.01) = 0.15			
LSD interaction (0.01) = 0.29			

4. DISCUSSION

4.1 PHYSICAL PARAMETERS

4.1.1 Firmness

In the present study, the application of 1-MCP significantly improved firmness retention of the papaya fruits for both ambient and cold storage conditions across all studied 1-MCP concentrations. This was due to the ability of 1-MCP to stop the action of endogenous ethylene. Application of 1-MCP prevented fruit softening and maintained its firmness. This result was in conformity with the results reported by Ashariya and Paull [3] who found that application of 1-MCP resulted in a significant delay in fruit softening. Also, these results were consistent with the findings of Iiana and Jacomino [16] who stated that papaya fruit treated with 1-MCP stayed firm and took a longer time to ripen compared to control fruits. Ethylene is vital for ripening and maturation. At the start of the process of ripening, the papaya fruit can have a deep physiological impact, minimal ethylene (0.1 ppm), due to its effect on the breakdown of enzymes responsible for chemical, physical and metabolic changes in the plant tissue, which impacts on the fruit taste and firmness [9].

Fruit firmness is related to a rise of pectin solubility and depolymerization of matrix polysaccharides which is thought to be a main contributor in reduced rigidity of cell walls that contributes to fruit softening [5]. The use of 1-MCP has reduced ethylene-induced softening and the results of the current study depicts that 1-MCP is able to shield the tissue against ethylene by hindering the binding site on the ethylene receptor as proposed by Sisler and Serek [28].

The reduction in firmness of papaya correlates well with the ethylene release. 1-MCP application inhibited ethylene production thus reduced the ethylene responses by suppressing the synthesis of degradation enzymes [4].

Consequently, treatment of papaya fruits with 0.5ppm 1-MCP is enough and economical to maintain firmness.

4.1.2 Cumulative Weight Loss (%)

Papaya fruit is a highly perishable fruit due to the high weight loss that occurs during storage [21]. Papaya is a climacteric fruit and is known to have a very short postharvest life involving weight loss, fast softening of the pulp, and the presence of microbial growth [14].

In the current study, 1-MCP treatment reduced weight loss in Solo papaya and the 1-MCP treated fruit experienced slower rate loss as related with control fruit during the storage. Weight loss is typically related to the loss of water or moisture in papaya tissues and attains the highest values during fruit marketing. Most of the water in papaya fruit is lost through the pedicel tissue and, to a lesser degree, through the cuticle tissue [25]. Manganaris *et al*. [18] applied 100 ng·kg-1 aqueous 1-MCP to plums and observed a reduction in weight loss, which was related to metabolic changes in cuticle waxes and also affected water vapor movement from the fruit outward. In herein presented study, there was a variation in cumulative weight loss with respect to storage condition as well as the varied concentrations of 1-MCP applied, which may have resulted from the variation in temperature and humidity of the cold and ambient storage condition employed. This variation in humidity may account for the higher rate of loss of moisture from the fruits to its environment in cold storage as compared to that of ambient storage, hence its replicating effect on cumulative weight loss of the stored papaya fruits. This could also be attributed to the presence of fungi and further tissue deterioration. Fruits treated with lower 1-MCP concentrations lost more weight and were statistically different that controls. Hence, 1-MCP could control weight loss in stored papaya fruits

Jeong *et al*. [17] also reported a delay in weight loss in 1-MCP treated avocado fruits compared with controls, but this delay was correlated with the suppression of ripening in general, and overall weight loss upon reaching a full-ripe condition.

Excessive weight loss can have undesirable effects on the overall quality of the fruit, such as a loss of firmness or color hence storage of Solo papaya fruits under ambient would be ideal in curtailing weight loss.

4.1.3 Colour of Fruit

Papaya treated with 1-MCP had less color change compared to the control. These results agree with those reported by Ashariya and Paull [3] who found that application of 1-MCP delayed color change in papaya fruit. Similar findings were also obtained by Manuel *et al*. [19] who worked on banana and found that application of 1-MCP prevented chlorophyll degradation due to its inhibition of chlorophyllase enzyme.

1-MCP application also slows down color change, yet its effect is subordinate compared to firmness retention. It is therefore rational to conclude that color development is less reliant on ethylene when related to softening process. According to Flores *et al*. [13], while loss of green color is ethylene dependent, breakdown of yellow pigments is not, this occurs even without the hormone presence. To slow down color change it would be ideal to use 0.5ppm of 1-MCP on fruit stored under cold storage.

4.1.4 SHELF LIFE

Fruits treated with 1-MCP has an extended shelf-life ability, expressed in days, compared to control. This was due to the inhibitory effect of 1-MCP on ethylene biosynthesis which delayed fruit ripening. However, with respect to the storage environments employed, shelf life in cold room storage was longer (8.87 days) than that of ambient storage (7.88 days) with respect the individual effects of storage condition. The individual effect of 1-MCP treatments recorded a higher shelf life as compared to the control of the experiment. Also, 1-MCP treatment prevented fruit softening, skin color development due to its adverse effects on ripening.

The results obtained were in conformity with those reported by Ashariya and Paull [3] who found that application of 1-MCP fruit of four maturity stages led to an increase in the number of days to ripening and maintained fruit firmness. The highest number of days to ripening was obtained with 1.5ppm 1-MCP treatment with cold storage environment temperature and relative humidity of 17.02 ^{o}C and 59.85% respectively. Paull *et al*. [24] also saw a rise in solubilisation of pectin and hemicelluloses as well as loss of firmness amid ripening which was improved by storage temperature and time.

4.2 STORAGE ENVIRONMENT

4.2.1 Temperature and Humidity

Numerous researches on mango and papaya and other tropical fruit observed that the higher the level of storage temperature and/or ripeness and the lower the relative humidity, the higher the rate of respiration [27]. The start of ripeness is mostly accompanied by a rise in respiration of the fruit. Fruits such as papaya (climacteric in nature) experience a rise in their ethylene biosynthesis patterns and respiration amid the process of ripening. This explains the results of this study as ambient storage environment, characterized by higher temperature and relative humidity, recorded higher respiration rate, hence higher rate of senescence and shorter shelf life compared to cold storage environment.

4.3 SENSORY EVALUATION

4.3.1 Peel Color

Considering the interactive effect of 1-MCP concentration and storage environment the color retention was highest in fruit treated with 1.5ppm 1-MCP of both ambient and cold room storage. The retention can be attributed to slow rate of respiration and metabolism due to the respiration and metabolism being positively correlated to colour change in papaya fruits. This was in agreement with Akamine and Goo [2] who stated the peak of total soluble solids in Solo variety papaya occurs when the yellow colour covers 6% of the papaya fruit peel. The peel color is regularly the main and first point of call-in post-harvest criterion for consumers, researchers, and growers to know if the papaya fruit is unripe or ripe [22].

4.3.2 Pulp Color

None of the treatments showed any significant differences of pulp colour with respect to the 1-MCP concentrations and the storage conditions. Excessively high temperature can cause peel browning, pitting, yellowing, abnormal softening, pulp darkening, increased decay and abnormal starch metabolism [8]. This may account for fruits stored in the cold room coming out with the best pulp color since the temperature was relatively low.

4.3.3 Firmness

Significant differences ($P \leq .01$) were detected in the interaction for the concentrations of 1-MCP applied and the storage methods used. The firmest fruits with respect to the interaction were fruits treated with 1.5ppm of 1-MCP under ambient storage condition and the fruits with the lowest firmness were fruits use as the control of the experiment (0ppm) under ambient storage conditions.

Fruit shelf life is reliant on firmness which is as a result of cell wall changes as a result of structural changes in non-starch and starch polysaccharides [34]. Loss of Firmness is also linked to physical and mechanical damage as well as disease conditions. 1-MCP in general retain firmness of fruits irrespective of the storage condition but its effects were best felt under ambient storage condition and this can be attributed to the higher loss of moisture to the environment in fruits stored under cold storage.

4.3.4 Taste

Fruits treated with 0.5ppm of 1-MCP and stored under cold storage recorded the best taste as it was liked a little. Fruits that were not treated with 1-MCP and stored in the cold room were generally the least preffered. This can be attributed to a good balance in sugar to acid ratio of the fruits tasted. Organic acid is imperative in having an anticipated sugar to acid balance which give rise to pleasing taste of fruit amid ripening. [2].

4.3.5 Aroma

0.5ppm of 1-MCP applied to Solo papaya and stored under cold storage recorded the best taste as it was liked a little. Control fruits were generally liked the least. Ripeness in papaya is coupled with fruity aroma. McGrath and Karahadian [20], reported that there is a relation between physicochemical changes and aroma development in papaya and this could be useful index for defining appropriate pawpaw maturity.

4.3.6 Texture

The best texture in relation to the results obtained can be associated with 1-MCP treated fruits at a concentration of 1.5ppm under cold room storage. The likeness of the textual feel is an index related to maturity and ripeness. Size, abscission force, color, texture, titratable acidity and changes in total soluble solids and physiological features such as respiration and ethylene production have been useful tools for maturity index development (Reid, 2002)

4.3.7 Overall Acceptance

In general, fruits treated with 1-MCP revealed a better acceptability as compared with fruits without 1-MCP treatment irrespective of the storage environment. The most acceptable, with respect to the results of the interaction effect, were the fruits treated with 1.5ppm 1-MCP, stored under ambient conditions. The least acceptable were control fruits stored under ambient storage conditions.

5. CONCLUSION

Fruits treated with 1-MCP and stored at ambient storage condition (26.08 °C and rH 82.58 %) and cold storage (17.02 °C, rH 59.85 %) were firmer than fruits that were not 1-MCP treated regardless of the storage condition.

Fruits firmness in cold storage was tendentially higher than in ambient storage, irrespective of the stage of color development but yielded no statistical difference. Firmness generally decreased as 1-MCP concentration was increased but the differences were not statistically significant. Thus, a treatment of Solo papaya with 0.5ppm of 1-MCP under cold should suffice for an adequate firmness retention during post-harvest.

The percentage of weight loss significantly decreased with increasing 1-MCP concentrations, but the differences were not statistically significant. However, variation in storage environments were statistically different with ambient stored fruits recording the lowest percentage of weight loss.

In light of the results obtained in the current study, to achieve a good weight retention, view post-harvest technologist are advised to treat their papaya fruits with 1ppm of 1-MCP and store them under ambient conditions. This will prevent wrinkles on the fruits surface and make the fruit more appealing to the consumer's eye.

It was generally observed that 1-MCP treated fruits exhibited a slower rate of color change as compared to fruits without 1-MCP treatment. With respect to ambient and cold storage environments, fruits stored under cold storage showed a lesser mean rate of change in peel color compared to fruits stored under ambient storage. With color change being a vital quality index for papaya ripeness, its determination along the papaya value change, should be treated as a priority quality parameter. The rate of color change should be regulated during transportation to ensure that the fruits reach their target markets at the ideal color stage, thus ensuring the market value is maintained if not increased. Thus, the rate of color change should be slowed down which could be achieved by applying 1-MCP treatment at 0.5ppm in both cold and ambient storage.

The shelf-life of the papaya fruits treated with 1.5ppm of 1-MCP and stored under ambient storage condition was extended by approximately 2 days. When the fruit were treated with the same concentration (1.5ppm) of 1-MCP but stored under colder conditions, the shelf life was extended by approximately 3 days.

The result of sensory evaluation revealed the panel preferred fruits treated with 1.5ppm of 1-MCP under ambient storage environment had the most acceptable level of firmness and overall acceptability. Hence this treatment would be ideal for the cut fruit market as well as the papaya fruit export market.

REFERENCES

1. Abutiate, W. S. Growing pawpaw in Ghana. A practical guide. Anansesem Publications. Ghana. 1995

2. Akamine, E.K. and Goo, T. relationship between surface colour development and total soluble solids in papaya. Horticultural Science 1971; 6; 567-568.

3. Ashariya, M. and Paull, R.E. Effect of 1-Methylcyclopropene (1- MCP) on papaya fruit ripening. Acta Horticulture 2007; 740; 323-326.

4. Blankenship, S.M. and Dole, J.M. 1-Methylcyclopropene: a review. Postharvest Biol. Tec. 2003; 28; 1-25.

5. Brummell, D.A. Cell wall disassembly in ripening fruit. Functional Plant Biol. 2006; 33; 103-119.

6. Brummell, D.A. and Harpster, M. H. cell wall metabolism in fruit softening and quality and its manipulation in transgenic plant. Plant Molecular Biology 2001; 47; 311-340.

7. Chiabrando, V. and Giacalone, G. Shelf-life extension of high bush blueberry using 1-Methylcyclopropene stored under air and controlled atmosphere. Food Chemistry, Berlin, 2011; 126(4); 1812-1816.

8. Dong, L., Lurie, S. and Zhou, H. Effect of 1-Methylcyclopropene on ripening of 'Canino' apricot and 'Royal Zee' plums. Postharvest Biology and Technology. 2002; 24; 135-145.

9. Dunkley, H.M.G. and Kerith D. ACC oxidase from Carica papaya: Isolation and characterization. Physiology Plantarum, 1998; 103; 225-232.

10. Egea, I., Flores, Martinez-Madrid, F.B., Romojaro, M.C., and Sánchez-Bel, F.P. 1-Methylcyclopropene affects the antioxidant system of apricots (Prunus armeniaca L. cv. Búlida) during storage at low temperature. Journal of the

11. FAO, Food loss prevention in perishable crops. Food and Agriculture Organization of the United Nations, Rome; 1981.

12. FFTC, Postharvest losses of fruit and vegetables in Asia. FFTC Survey, 1993. Food and Fertilizer Technology Center, 2005. Taiwan. Accessed 29 November 2018. Available: http://www.agnet.org/library/ article/aci 993d.html.

13. Flores, F., Ben Amor, M., Jones, B., Pech, J.C., Bouzayen, M., Latché, A. and Romojaro, F. The use of ethylene-suppressed lines to assess differential sensitivity to ethylene of the various ripening pathways in Cantaloupe melons. Physiologia Plantarum, Copenhagen. 2001; 113; 128133.

14. Gonzalez-Aguilar, G. A., Valenzuela-Soto, E., Lizardi-Mendoza, J., Goycoolea, F., Martinez-Tellez, M. A. and Villegas-Ochoa, M. A. Effect of chitosan coating in preventing deterioration and preserving the quality of fresh-cut papaya 'Maradol'. Journal Science Food Agriculture. 2009; 89; 15–23.

15. Hamzah, H.M., Osman, A., Tan, C.P. and Ghazali, F.M. Carrageenan as an alternative coating for papaya (Carica papaya L. cv. Eksotika). Postharvest Biology and Technology. 2013; 75; 142-146.

16. Iiana, U.B. and Jacomino, A.P. Ethylene action blockade and cold storage effect on ripening of 'Golden' papaya fruit. Acta Physiology of Plant 2009; 25; 336-345.

17. Jeong J, Huber DJ, Sargent SA. Influence of 1-methylcyclopropene (1- MCP) on ripening and cell-wall matrix polysaccharides of avocado (Persea americana) fruit. Postharvest Biology Technology. 2002; 25:241–56.

18. Manganaris, G.A., Crisosto, C., Bremer, V. and Holcroft, D. Novel 1-Methylcyclopropene immersion formulation extends shelf life of advanced maturity 'Joanna Red' plums (Prunus salicina, Lindell). Postharvest Biology Technology 2008; 47; 429–433.

19. Manuel, B., Siller, J.S., Ranged, D.M. and Heredia, J.B. Extending the shelf life of bananas with 1-methylene cyclopropene and a chitosan– based edible coating. Journal of the Science of Food and Agriculture; 2009.

20. McGrath, M. J. and Karahadian, C. Evaluation of physical, chemical and sensory properties of pawpaw fruit as indicators of ripeness; 1994.

21. McGregor, B.M. Tropical products handbook transport. U.S. Department of Agriculture, Agriculture Handbook 1987; 668; 148.

22. Medlicott, A., "Product Specifications and Postharvest Handling for Fruits, Vegetables and Root Crops Exported from the Caribbean"). Global Agribusiness Information network (GAIN); 2001.

23. Paul, V., Pandey, R. and Srivastava, G.C. Ripening of tomato (Solanum lycopersicum L.). Part I: 1-Methylcyclopropene mediated delay at higher storage temperature. Journal of Food Science and Technology, Oxford, 2010; 47(5); 519-526.

24. Paull, R., Gross K. and Qiu Y. Changes in papaya cell wall during fruit ripening. Postharvest Biology Technology. 1999; 16; 79-89.

25. Paull, R.E. and Chen, N.J. Waxing and plastic wrap influence water loss from papaya fruit during storage and ripening. J. Amer. Soc. Hort. Sci. 1989; 114(6); 937-942.

26. Pereira, M.E.C. Sargent, S.A. Sims, C.A. Huber, D.J. Moretti, C.L. Crane, J.H. Aqueous 1-Methylcyclopropene extends longevity and does not affect sensory acceptability of Guatemalan-West Indian hybrid avocado. Horticultural Technology, Alexandria. 2013; 23(4); 468-473.

27. Rivera-López, J., Vásquez-Ortiz, F. A., Ayala-Zavala, J. F., Sotelo-Mundo, R. R. and González-Aguilar, G. A. Cutting shape and storage temperature affect overall quality of fresh-cut papaya 'Maradol'. Journal of Food Science. 2005; 70; 482–489.

28. Sisler, E.C., Dupille, E. and Serek, M. Effect of 1-Methylcyclopropene and methylenecyclopropane on ethylene binding and ethylene action on cut carnations. Plant Growth Regulation, Dordrecht. 1997; 18; 79-86.

29. Tiwari, K. and Paliyath, G. Microarray analysis of ripening-regulated gene expression and its modulation by 1-MCP and hexanal. Plant Physiology and Biochemistry, Kalyani. 2011; 49(3); 329-340.

30. Trevisan, M.J., Jacomino, A.P., Cunha Junior, L.C. and Alves, R.F. Aplicação De 1-metilciclopropeno associado ao etileno para minimizar seus efeitos na inibição do amadurecimento do mamão 'golden'. Revista Brasileira de Fruticultura, Jaboticabal, 2013; 35(2); 384-390.

31. Vieira, M.J., Argenta, L.C., Amarante, C.V.T. and Do Vieira, A.M.F.D. and Steffens, C.A. Qualidade pós-colheita de quivi 'Hayward' tratado com 1-MCP e armazenado sob diferentes atmosferas. Revista Brasileira de Fruticultura, Jaboticabal. 2012; 34 (2); 400-408. French.

32. Waghmare, R.B. Anna pure U.S. Combined effect of chemical treatment and/or modified atmosphere packaging (MAP) on quality of freshcut papaya. Postharvest Biology and Technology, 2013; 85; 147-153.

33. Watkins, C. B. and Nock, J. F. Rapid 1-Methylcyclopropene (1-MCP) treatment and delayed controlled atmosphere storage of apples. Postharvest Biology and Technology, Amsterdam. 2012; 69; 24-31.

34. Yashoda, H. M., Prabha N.K. and Tharanathan R.N. Mango ripening changes in cell wall. Constituents in relation to textural softening. Journal for Science Food Agriculture; 2006.

35. Zhang, Z., Tian, S., Zhu, Z., Xu, Y. and Qin, G. Effects of 1-Methylcyclopropene (1-MCP) on ripening and resistance of jujube (Zizyphus jujube cv. Huping) fruit against postharvest disease. LWT Food Science and Technology, Amsterdam. 2012; 45(1); 13-19.

APENDIX

Analysis of Variance Table for Firmness

Source	DF	SS	MS	F	P
Storage	1	1.89	1.887	0.22	0.6432
1-MCP	3	1729.05	576.349	68.09	0.0000
Storage*MCP	3	13.74	4.581	0.54	0.6610
Error	16	135.42	8.464		
Total	23	1880.10			

Grand Mean 52.938 CV 5.50

Analysis of Variance Table for TSS

Source	DF	SS	MS	F	P
Storage	1	3.2487	3.24870	106.25	0.0000
1-MCP	3	5.9137	1.97125	64.47	0.0000
Storage*MCP	3	3.5473	1.18245	38.67	0.0000
Error	16	0.4892	0.03057		
Total	23	13.1990			

Grand Mean 9.8346 CV 1.78

Analysis of Variance Table for TTA

Source	DF	SS	MS	F	P
Storage	1	0.00400	0.00400	6.91	0.0182
1-MCP	3	0.00538	0.00179	3.10	0.0566
Storage*MCP	3	0.00385	0.00128	2.21	0.1261
Error	16	0.00927	0.00058		
Total	23	0.02250			

Grand Mean 0.2729 CV 8.82

Analysis of Variance Table for Vitamin C

Source	DF	SS	MS	F	P
Storage	1	0.21660	0.21660	3.60	0.0759
MCP	3	0.26243	0.08748	1.45	0.2642
Storage*MCP	3	0.50210	0.16737	2.78	0.0746
Error	16	0.96200	0.06013		
Total	23	1.94313			

Grand Mean 3.1317 CV 7.83

Analysis of Variance Table for pH

Source	DF	SS	MS	F	P
Storage	1	0.09500	0.09500	814.32	0.0000
1-MCP	3	0.27951	0.09317	798.61	0.0000
Storage*MCP	3	0.02038	0.00679	58.23	0.0000
Error	16	0.00187	0.00012		
Total	23	0.39676			

Grand Mean 5.8063 CV 0.19

Analysis of Variance Table for Percentage Weight Loss

Source	DF	SS	MS	F	P
Storage	1	0.16834	0.16834	20.50	0.0003
1-MCP	3	0.06371	0.02124	2.59	0.0892
Storage*MCP	3	0.00245	0.00082	0.10	0.9593
Error	16	0.13140	0.00821		
Total	23	0.36590			

Grand Mean 1.2671 CV 7.15

Analysis of Variance Table for Colour Change

Source	DF	SS	MS	F	P
Storage	1	0.1218	0.12184	2.45	0.1373
1-MCP	3	29.3390	9.77966	196.38	0.0000
Storage*MCP	3	0.3831	0.12769	2.56	0.0910
Error	16	0.7968	0.04980		
Total	23	30.6407			

Grand Mean 3.9171 CV 5.70

Analysis of Variance Table for Humidity

Source	DF	SS	MS	F	P
Storage	1	30987.8	30987.8	1145.55	0.0000
Error	238	6438.0	27.1		
Total	239	37425.8			

Grand Mean 71.213 CV 7.30

Analysis of Variance Table for Temperature

Source	DF	SS	MS	F	P
Storage	1	4925.92	4925.92	6133.10	0.0000
Error	238	191.15	0.80		
Total	239	5117.08			

Grand Mean 21.546 CV 4.16

Analysis of Variance Table for Aroma

Source	DF	SS	MS	F	P

1-MCP Conce	3	4.3262	1.44207	6.27	0.0004
Storage	1	0.1494	0.14939	0.65	0.4208
1-MCP Conce*Storage	3	0.6433	0.21443	0.93	0.4251
Error	320	73.5610	0.22988		
Total	327	78.6799			

Grand Mean 2.6494 CV 18.10

Analysis of Variance Table for Firmness

Source	DF	SS	MS	F	P
1-MCP Conce	3	48.180	16.0600	67.10	0.0000
Storage	1	0.247	0.2470	1.03	0.3105
1-MCP Conce*Storage	3	0.473	0.1575	0.66	0.5783
Error	320	76.585	0.2393		
Total	327	125.485			

Grand Mean 2.5396 CV 19.26

Analysis of Variance Table for Overall

Source	DF	SS	MS	F	P
1-MCP Conce	3	47.155	15.7185	59.57	0.0000
Storage	1	0.076	0.0762	0.29	0.5913
1-MCP Conce*Storage	3	0.082	0.0274	0.10	0.9577
Error	320	84.439	0.2639		
Total	327	131.753			

Grand Mean 2.4726 CV 20.78

Analysis of Variance Table for Peel

Source	DF	SS	MS	F	P
1-MCP Conce	3	12.3018	4.10061	20.72	0.0000
Storage	1	0.0030	0.00305	0.02	0.9013
1-MCP Conce*Storage	3	0.0091	0.00305	0.02	0.9974
Error	320	63.3171	0.19787		
Total	327	75.6311			

Grand Mean 2.7835 CV 15.98

Analysis of Variance Table for Taste

Source	DF	SS	MS	F	P
1-MCP Conce	3	6.1555	2.05183	8.19	0.0000
Storage	1	0.0762	0.07622	0.30	0.5817
1-MCP Conce*Storage	3	0.6921	0.23069	0.92	0.4311
Error	320	80.1951	0.25061		
Total	327	87.1189			

Grand Mean 2.5518 CV 19.62

Analysis of Variance Table for Texture

Source	DF	SS	MS	F	P
1-MCP Conce	3	63.829	21.2764	54.97	0.0000
Storage	1	0.598	0.5976	1.54	0.2149
1-MCP Conce*Storage	3	1.280	0.4268	1.10	0.3481
Error	320	123.854	0.3870		
Total	327	189.561			

Grand Mean 2.5366 CV 24.53

Analysis of Variance Table for Pulp Colour

Source	DF	SS	MS	F	P
1-MCP Conce	3	1.1067	0.36890	1.54	0.2037
Storage	1	0.0030	0.00305	0.01	0.9102
1-MCP Conce*Storage	3	0.6677	0.22256	0.93	0.4265
Error	320	76.5854	0.23933		
Total	327	78.3628			

Grand Mean 2.6311 CV 18.59

Analysis of Variance Table for Shelf life

Source	DF	SS	MS	F	P
1-MCP	3	58.625	19.5417	12.09	0.0000
Storage	1	29.008	29.0083	17.94	0.0000
1-MCP*Storage	3	5.425	1.8083	1.12	0.3447
Error	112	181.067	1.6167		
Total	119	274.125			

Grand Mean 8.3750 CV 15.18