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Effect of Postharvest Application of Different Concentrations of 1-Methylcylclopropene on Quality and Shelf-life of Two Tomato (*Solanum lycopersicum*) Cultivars

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Authors' contributions

This work was carried out in collaboration with all authors. Author MEA designed the study and performed the statistical analysis. Authors MEA and IY wrote the protocol as well as the first draft of the manuscript. Author IY managed the analyses of the study. Author PK supervised the work, read and approved the final manuscript.

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ABSTRACT

Two tomato cultivars harvested at the mature-green stage were studied to determine the effect of postharvest application of different concentrations of 1-Methylcyclopropene (1-MCP) on their quality and shelf-life. A 2 x 3 factorial arrangement in Completely Randomized Design (CRD) with three replications were used. The two cultivars 'Eva' and 'Power' were each treated with 1 ppm and 2 ppm of 1-MCP concentrations and the untreated were considered as control (0 ppm).The fruits were placed inside air-tight plastic barrels with different 1-MCP concentrations at an average temperature of 29.5°C and relative humidity of 60-75%. The 1-MCP gas was allowed to circulate in the airtight barrels with the aid of a mini fan which was attached to the lid of the barrel for 24 hours before the fruits were brought out, displayed and physico-chemical properties and shelf-life monitored. The results showed that higher concentrations of the 1-MCP (2 ppm) significantly

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(P≤0.01) delayed ripening as measured by changes in colour, total soluble solids and total titratable acidity. Generally, between the cultivars, 'Eva' fruits were significantly (P≤0.01) firmer irrespective of the 1-MCP concentration. Significantly (P≤0.01), untreated fruits (0 ppm) of both cultivars recorded higher moisture and vitamin C contents than treated fruits (1 and 2 ppm). Tomatoes treated with 1 ppm and 2 ppm of 1-MCP concentrations had delayed ripening (longer green-life) and as a result had a longer shelf-life (89 and 104 days, respectively) compared to untreated tomatoes (77 days). Clearly, the results of this research has established that the use of 1-MCP have marketable prospect for growers and traders to delay the ripening of tomatoes.

Keywords: Mature green; tomato cultivars; 1-MCP; physico-chemical and shelf-life.

1. INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetables cultivated worldwide [1]. In Ghana, it is an indispensable ingredient in the daily meals of people across all regions [2]. Tomato which is a tropical perennial crop belongs to the nightshade family Solanaceae [3]. Tomato has attracted the attention of many people in recent years as a result of its antioxidant and anticarcinogenic property conferred by its ascorbic acid and lycopene content [4]. The fruit can be used as vegetable served with rice and salads. It is used principally in Ghana in stews and soups [5]. Tomatoes are rich in vitamin C, carotenoids and flavonoids. They exist in abundance with vital nutrients such as minerals and vitamins [6].

Tomato is a very nutritious vegetable which is highly perishable. Due to its fast rate of ripening there are huge produce losses during handling. Global production of fresh tomato fruit by FAO is about 78.28 million tons cultivated on 2.8 million hectares [7]. It was reported by [8] that it has been estimated that, in developing countries about 40-60% of tomatoes are lost after harvest and this leads to higher market prices. Hence, a reduction in postharvest losses is very crucial in getting back the grower's production cost and also improving the living conditions of those in the tomato industry.

In order to overcome this problem, several postharvest interventions have been introduced to help maintain quality and extend shelf-life of these perishable crops. These interventions include low temperature storage, high relative humidity, controlled atmosphere storage and others [9]. There is a market benefit that is being derived both local and foreign when the shelf-life of tomato is extended [10]. According to [11], 1-MCP is a member of a class of compounds called cyclopropenes which could inhibit ethylene perception by binding aggressively to ethylene receptors delaying ripening and improve the storage life of perishable crops. The introduction of 1-MCP is a major discovery in controlling ethylene responses of horticultural products. Flavor and aroma, nutritional properties, pigments, cell wall metabolism and softening are among some of the senescence and ripening processes that are influenced by 1-MCP [12 -14].

Many tomato producers around the world adopt refrigeration to delay ripening. However, this is expensive for farmers in Ghana. 1-MCP application has been reported to retard softening of banana and 'ginger gold' apples respectively thereby maintaining the quality and extending the shelf-life [15,16]. There is, however, scanty information on how different concentrations of 1-MCP affect the quality and shelf-life of tomatoes. Hence this study into the use of 1-MCP on the quality of tomato.

The study will contribute to scientific knowledge on the application of 1-MCP and its influence on the quality of tomatoes.

2. MATERIALS AND METHODS

2.1 Sources of Material and Experimental Site

Tomato fruits, 'Power' and 'Eva' cultivars, were harvested at the mature-green stage from a greenhouse at Asokore-Mampong in the Ashanti region of Ghana. The harvesting was done 7 weeks after transplanting. The tomato fruits were sorted and graded to make sure that the fruits selected for the experiment were clearly free from diseases and blemishes. The two cultivars were then packed into separate wooden boxes with ventilation holes. They were then conveyed within 30 minutes to the laboratory of the Department of Horticulture, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi. The research was started in February, 2017 after an initial trial of the research in January 2017 at the laboratory of the Department of Horticulture, Kwame Nkrumah University of Science and Technology (KNUST) in Kumasi.

2.2 Experimental Design

A 2 x 3 factorial arrangement in a Completely Randomized Design (CRD) with three replications were used. This comprised of 2 different cultivars of tomatoes; 'Power' and 'Eva' and 2 different concentrations of 1-MCP; 1 ppm and 2 ppm and the control at 0 ppm.

2.3 Fruit Treatment

The tomato fruits selected for the experiment were washed under tap water and air dried. The fruits (180) each for 'Power' and 'Eva' cultivars were distributed into three groups. The first group was treated with 1 ppm, the second group was treated with 2 ppm of 1-MCP concentrations (both prepared from Maxfresh, 3.3%) and the third group was untreated (control). The 1-MCP powder was dissolved in lukewarm water to obtain the various concentrations and placed inside air-tight plastic barrels where the fruits were kept. The 1-MCP gas was allowed to circulate in the air-tight barrels with the aid of a mini fan which was attached to the lid of the barrel for 24 hours before the fruits were brought out and displayed. The physico-chemical properties were monitored along the six ripening colour stages of tomato and the mean values were presented in tables. The shelf-life was also monitored. The set-up was allowed to stay under ambient conditions (average temperature of 29.5°C and relative humidity of 60-75%).

2.4 Parameters Assessed

2.4.1 Rate of colour change

The colour change of the fruit was determined using a colour chart [17], which had a scale of 1-6. The number of days taken for the tomatoes to change from mature-green (1) to full-ripe (6) was used as the rate of colour change.

2.4.2 Weight loss

The weight (g) of the fruits was initially taken for all treatments and subsequently weighed daily for all individual fruits until the individual fruits were considered unmarketable or it starts to rot. The losses in weight were calculated as: accumulated weight loss percentage from the initial weight of the fruit [18].

2.4.3 Firmness

A digital Durometer (LX-C type, China) was used to check the firmness of the tomato fruit. The fruit was held on both sides and force was applied to constantly compress the spring on the fruit. The constant pressing allows the anvil to measure the firmness of the fruit. The values were expressed in Newton [9].

2.4.4 Vitamin C content

This was determined by using 2, 6-Dichloroindophenol Titrimetric method and the results reported as mg/100g of tomato fruit [19].

2.4.5 Total Titratable Acidity (TTA)

10ml of juice from the various treatments were titrated against 0.1M NaOH and the results were expressed in percentage citric acid [20].

2.4.6 Total Soluble Solids (TSS)

The TSS was determined by the use of digital refractometer (Reed MT-032 Brix Refractometer, Taiwan) and the value reported in degree brix [18].

2.4.7 Moisture content

The weight of moisture can was initially taken and subsequently a slice of the tomato (2 grams) was then added to the moisture can and weighed together. The can together with the tomato samples were oven dried for 24 hours at a temperature of 60°C and re-weighed again [21]. The moisture was then calculated as the percentage of moisture that evaporated in the oven.

2.4.8 Shelf-life

The shelf-life of the tomatoes was assessed from the time they were harvested to the time they became unmarketable that is; shows signs of rotting or over-ripe [22].

2.5 Statistical Analysis

The data generated were statistically analyzed using Statistix software version 9. The data was subjected to Analysis of Variance (ANOVA) using the Tukey's Honesty Significant Difference (HSD) test at 1% ($P \leq 0.01$). The results were presented in tables.

3. RESULTS

3.1 Rate of Colour Change (days) of the Two Tomato Cultivars Treated with Different Concentrations of 1-MCP

Between the cultivars, a significant ($P \leq 0.01$) delay in colour change was recorded by 'Eva' fruits (101 days) whilst a rapid colour change was recorded by 'Power' fruits (64 days).

With reference to the cultivars and 1-MCP concentrations interaction, a significant ($P \leq 0.01$) delay in colour change was observed by 'Eva' fruits treated with 2 ppm of 1-MCP concentration (113 days) whilst a rapid colour change was observed by untreated (0 ppm) 'Power' fruits (53 days) as shown (Table 1).

3.2 Percentage (%) Weight Loss of the Two Tomato Cultivars Treated with Different Concentrations of 1-MCP

Between the cultivars, 'Power' fruits recorded a significantly higher ($P \leq 0.01$) weight loss of 0.62% and the lowest was 0.35% by 'Eva' fruits.

Again, amongst the cultivars and 1-MCP concentrations interaction, untreated 'Power' fruits (0 ppm) had a significantly higher ($P \leq 0.01$) weight loss of 0.67% and the lowest of 0.29% was recorded by 'Eva' fruits treated with 2 ppm of 1-MCP concentration as shown (Table 2).

3.3 Firmness (N) of the Two Tomato Cultivars Treated with Different 1-MCP Concentrations

There was a significant difference between the mean of the cultivars on firmness. 'Eva' fruits had a significantly ($P \leq 0.01$) firmer fruits (60.1 N) compared to 'Power' fruits which were firm (50.6 N). The firmness of the tomatoes did not vary significantly when treated with the concentrations of 1-MCP.

Interactively, firmer fruits (60.8 N) were recorded when 'Eva' fruits were treated with 2 ppm of 1-MCP concentration which was similar to 'Eva' fruits treated with 1 ppm and untreated (0 ppm). 'Power' cultivars on the other hand recorded firm fruits (46.1 N) when no 1-MCP concentration (0 ppm) was applied which was also similar to 'Power' fruits treated with 1 ppm and 2 ppm as represented (Table 3).

3.4 Vitamin C (mg/100 mg) of the Two Tomato Cultivars Treated with Different Concentrations of 1-MCP

Significantly higher ($P \leq 0.01$) vitamin C content of 5.90 mg/100mg was recorded by 'Power' fruits and the lowest of 3.81 mg/100mg was by 'Eva' fruits.

Interactively, 'Power' fruits to with no 1-MCP concentration was applied (0 ppm) had a significantly ($P \leq 0.01$) higher vitamin C content of 7.87 mg/100mg and the lowest vitamin C content of 3.18 mg/100mg was recorded by 'Eva' fruits treated with 2 ppm of 1-MCP concentration as indicated (Table 4).

3.5 Total Titratable Acidity (TTA %) of the Two Tomato Cultivars Treated with Different Concentrations of 1-MCP

There was no significant difference ($P > 0.01$) between the cultivars.

There was also a significant variation in the TTA of tomato when treated with 1-MCP, with the higher dose resulting in the highest TTA.

Amongst the 1-MCP concentrations and cultivars interaction, 'Eva' fruits treated with 2 ppm of the 1-MCP concentration had a significantly higher ($P \leq 0.01$) TTA of 0.47% and the lowest TTA of 0.17% was recorded by untreated 'Power' fruits (0 ppm) as observed (Table 5).

Table 1. Rate of Colour changes (days) in the two tomato cultivars treated with different concentrations of 1-MCP

Rate of colour change (Days)				
Cultivars	**1-MCP concentrations**			
	0 ppm	**1 ppm**	**2 ppm**	**Mean**
'Eva'	93b	96b	113a	101a
'Power'	53e	65d	74c	64b
Mean	73c	81b	93a	

HSD (1%) cultivars = 1.85, cultivars x 1-MCP Concentrations = 4.36

Table 2. Percentage (%) Weight loss of the two tomato cultivars treated with different concentrations of 1-MCP

	Weight loss (%)			
Cultivars	**1-MCP concentrations**			
	0 ppm	**1 ppm**	**2 ppm**	**Mean**
'Eva'	0.44bc	0.32cd	0.29d	0.35b
'Power'	0.67a	0.67a	0.52b	0.62a
Mean	0.56a	0.49a	0.41b	

HSD (1%) cultivars = 0.06, cultivars x 1-MCP Concentrations = 0.13

Table 3. Firmness (N) of the two tomato cultivars treated with different 1-MCP concentrations

	Firmness (N)			
Cultivars	**1-MCP concentrations**			
	0 ppm	**1 ppm**	**2 ppm**	**Means**
'Eva'	59.3a	60.3a	60.8a	60.1a
'Power'	46.1b	52.2b	53.5ab	50.6b
Mean	53.4a	56.3a	56.4a	

HSD (0.01) cultivars = 3.71, cultivars x 1-MCP Concentrations = 8.73

Table 4. Vitamin C (mg/100 mg) of the two tomato cultivars treated with different concentrations of 1-MCP

	Vitamin C (mg/100 mg)			
Cultivar	**1-MCP concentrations**			
	0 ppm	**1 ppm**	**2 ppm**	**Mean**
'Eva'	4.47c	3.78de	3.18e	3.81b
'Power'	7.87a	5.46b	4.37cd	5.90a
Mean	6.17a	4.62b	3.78c	

HSD (1%) cultivars = 0.28, cultivars x 1-MCP Concentrations =0.65

Table 5. Total Titratable Acidity (TTA %) of the two tomato cultivars treated with different concentrations of 1-MCP

	Total Titratable Acidity (%)			
Cultivars	**1-MCP concentrations**			
	0 ppm	**1 ppm**	**2 ppm**	**Mean**
'Eva'	0.19c	0.22c	0.47a	0.29a
'Power'	0.17c	0.32b	0.42a	0.30 a
Mean	0.19c	0.31b	0.39a	

HSD (1%) cultivars = 0.03, cultivars x 1-MCP Concentrations = 0.08

3.6 Total Soluble Solids (TSS) of the Two Tomato Cultivars Treated with Different Concentrations of 1-MCP

'Power' fruits recorded a significantly higher (P≤0.01) TSS of 4.98 °Brix and the lowest TSS of 3.98 °Brix was recorded by 'Eva' cultivars.

Amongst the 1-MCP concentrations and cultivars interaction, the TSS of 'Power' fruits treated with 2 ppm of 1-MCP concentration was significantly higher (P≤0.01) (5.55 °Brix) which was similar to 'Power' fruits treated with 1 ppm (5.05 °Brix) of 1-MCP concentration. Also untreated 'Power' fruits had the least TSS (4.35 °Brix). On the other hand, 'Eva' fruits treated with 1 ppm and 2 ppm of the 1-MCP concentrations did not vary significantly from the untreated (0 ppm).

3.7 Moisture Content (%) of the Two Tomato Cultivars Treated with Different Concentrations of 1-MCP

Between the cultivars, there was a significant cultivar difference (P≤0.01) in moisture content with 'Eva' fruits having a higher moisture content of 94.3% compared to 'Power' fruits with the lowest moisture content of 92.5%.

Interactively, there was no significant difference on 'Eva' fruits untreated (0 ppm) as well as the treated fruits (1 ppm and 2 ppm). On the other hand, there was also no significant difference on 'Power' fruits treated with the 1-MCP concentration (1 ppm and 2 ppm) as well as the untreated (0 ppm) as observed in Table 7.

3.8 Shelf-life (days) of the Two Tomato Cultivars Treated with Different Concentrations of 1-MCP

Between the cultivars, 'Eva' fruits recorded a significantly longer ($P \leq 0.01$) shelf-life of 106 days and a shorter shelf-life of 74 days was recorded by 'Power' fruits.

With reference to cultivars and 1-MCP concentrations interaction, 'Eva' fruits treated with 2 ppm of 1-MCP concentration had a significantly longer ($P \leq 0.01$) shelf-life of 122 days and a shorter shelf-life of 65 days was recorded by untreated 'Power' fruits which was similar to 'Power' treated with 1 ppm as indicated (Table 8).

4. DISCUSSION

4.1 Rate of Colour Change

Generally, rapid colour change was observed in 'Power' fruits where it took 64 days to change colour from mature green to fully red stage compared to 'Eva' fruits which took 101 days could be as a result of genetic variation of the cultivars that result in slower rate of attractive red colour development in 'Eva' fruits compared to 'Power' fruits.

Interactively, a delay in colour change from mature green to red ripe stage by 'Eva' fruits treated with 2 ppm of 1-MCP concentration could be ascribed to the fact that, the highest dose of 1-MCP treatment (2 ppm) delayed the synthesis of lycopene which according to [23] is the main constituent of carotenoid representing 98% of carotenoid and which gives the fruit its characteristic red colour. It could be that 1-MCP treatment retarded the lycopene synthesis by blocking the ethylene receptors and as a result restricted its effect on the fruit thus delaying its colour change. Such restrictive effect of 1-MCP treatment affirmed the results similar to previous studies by [24] and [25]. In a related development, it was also reported by [26], that 1-MCP is crucial for increasing the postharvest shelf-life and delaying colour changes in the skin of produce.

4.2 Weight Loss

Between the cultivars, the highest weight loss recorded by 'Power' fruits compared to 'Eva' fruits could be attributed to the difference in cultivars. 'Power' fruits had a thin fruit skin and as a result underwent rapid deterioration during ripening compared to 'Eva' fruits which had a thicker fruit skin and as a result underwent slower rate of deterioration in the course of ripening.

The highest weight loss recorded by untreated 'Power' fruits (control) with regard to cultivars and 1-MCP treatments interaction could be due to an increased respiration and transpiration rate which in turn led to water loss in the fruit.

It was mentioned by [27] that, the major means that result in weight loss in most fresh produce is through transpiration and in tomato fruit about 92-97% of the weight loss is due to transpiration.

The lowest weight loss recorded by 'Eva' fruits at 2 ppm of 1-MCP concentration might be attributed to the fact that, the 1-MCP concentration applied was able to penetrate the tissues of the fruits to retard the physiological and respiratory processes that promote water loss in fruits and as a result inhibited weight loss.

Table 6. Total soluble solids (TSS) of the two tomato cultivars treated with different concentrations of 1-MCP

	Total Soluble Solids (°Brix)			
Cultivars	**1-MCP concentrations**			
	0 ppm	**1 ppm**	**2 ppm**	**Mean**
'Eva'	3.91c	4.04c	3.98c	3.98b
'Power'	4.35bc	5.05ab	5.55a	4.98a
Mean	4.73a	4.19b	4.51ab	

HSD (1%) cultivars = 0.31, cultivars x 1-MCP Concentrations = 0.72

Table 7. Moisture content (%) of the two tomato cultivars treated with different concentrations of 1-MCP

	Moisture content (%)			
Cultivars	1-MCP concentrations			
	0 ppm	1 ppm	2 ppm	Mean
'Eva'	94.9 a	94.1ab	94.0ab	94.3 a
'Power'	92.9ab	92.6b	92.2b	92.5b
Mean	93.9a	93.3a	93.1a	

HSD (1%) cultivars = 0.98, cultivars x 1-MCP Concentration =2.31

Table 8. Shelf-life (days) of the two tomato cultivars treated with different concentrations of 1-MCP

	Shelf-life (days)			
Cultivars	1-MCP concentrations			
	0 ppm	1 ppm	2 ppm	Mean
'Eva'	88c	107b	122a	106a
'Power'	65d	71d	85c	74b
Mean	77c	89b	104a	

HSD (1%) cultivars = 2.82, cultivars x 1-MCP Concentrations = 6.64

Zhiguo et al. [27] reported that the lowest weight loss in the treated samples may be due to the reduced transpiration rate. 1-MCP significantly reduced weight loss at all concentrations. The fruits treated with 1-MCP concentration delayed an increase in weight loss percentage of the tomato fruits.

4.3 Firmness

Firm fruits recorded by 'Power' cultivar compared to firmer by 'Eva' cultivar could be attributed to higher rate of metabolic activities and activity of cell wall degrading enzymes that loosens the fruits skin of 'Power' fruits which led to higher permeability of the cell for higher rate of moisture loss. Moisture loss also promotes wilting, shrinkage and loss of firmness [28]. This therefore could have accounted for why firm fruits were obtained by 'Power' cultivar compared to firmer by 'Eva' cultivar.

With reference to cultivars and 1-MCP treatment interactions, the firmest fruits by 'Eva' cultivar treated with 2 ppm of the 1-MCP concentration might partly be that the 1-MCP concentration applied blocked the ethylene receptors from synthesizing ethylene which aids in ripening in the fruits. However the activity of the enzyme Polygalacturonase (PG) which according to [29] appears as fruits begins to change colour and continues to increase during ripening was also prevented and as a result loss in firmness was reduced leading to firmer fruits. Higher dose of 1-MCP concentration applied extensively prohibited the increase of (PG) activity and as such it could be deduced that the activities were lowered by 1-MCP application on fruits.

The untreated 'Power' fruits (0 ppm) were firm and this could be attributed to the absence of an ethylene blocker (1-MCP) that suppressed the production and effect of ethylene on the fruits. Also the activities of certain enzymes known for loss in firmness were hastened as these enzymes occur when ripening is taking place. According to [10], firmness is a vital indicator for assessing the quality of fresh produce. Mostly, the ripening of the fruit is associated with a decrease in firmness.

4.4 Vitamin C Content

The higher vitamin C level recorded by 'Power' fruits compared to 'Eva' fruits between the cultivars might partly be attributed to their nutritional composition that is conferred by their genetic makeup. According to [30], the cultivar, maturity of fruit and the growing season are amongst the important factors that determined the differences in nutritional composition and that additional changes can happen in the course of postharvest handling and storage.

The lowest vitamin C content in 'Eva' fruits at 2 ppm of 1-MCP treatment could be attributed to an increased activity of the enzymes; cytochrome oxidase, ascorbic acid oxidase and peroxidase and inhibition of ascorbate biosynthetic pathway. These enzymes according to [31] are enzymes that contribute to low ascorbic acid content in fresh cut oranges. Similarly, [32] also observed lower levels of vitamin C with the postharvest application of 1-MCP on 'Tegan Blue' Japanese plum.

Higher vitamin C content by the untreated 'Power' fruits amongst the cultivars and 1-MCP treatments interaction could be attributed to decreased activities of enzymes; cytochrome oxidase, ascorbic acid oxidase and peroxidase which contributes to higher vitamin c content.

4.5 Total Titratable Acidity (TTA)

The lower TTA by the untreated 'Power' fruits (control) between the cultivars could be of increased ripening which is matched with a faster rate of colour change. As fruits starts to ripen, there is an increase in sugars and a decrease in acidity and so in the absence of 1-MCP which is an ethylene blocker to block ethylene which aids in ripening, the fruits ripened at a faster rate thus leading to a reduction in acidity.

The highest TTA level recorded by 'Eva' fruits at 2 ppm of the 1-MCP concentration with reference to 1-MCP and cultivars interaction could be as a result of the effect 1-MCP concentration applied had on the fruits. The highest dose of 1-MCP concentration was able to block the ethylene receptors and elicit its physiological actions that cause the early ripening of the tomato. 1-MCP significantly restricted increases in total titratable acidity. The enzyme alcohol dehydrogenase is found in tomato and uses organic acids as respiratory substrates as reported by [33] and its activity increases in the course of ripening and contributes to flavour or taste development. It could be that the highest dose of the 1-MCP concentration (2 ppm) was able to block the enzyme (Alcohol dehydrogenase) which facilitates ripening and as a result reduces the rate of conversion of sugars to acids.

The retention of acidity in fruits treated with (2 ppm) of 1-MCP application might also be due to a reduction in the respiratory process when 1-MCP concentration was applied.

A reduction in citric acid, a major contributor to TTA which occurs during ripening was suppressed by the ethylene inhibitor (1-MCP) thus leading to a higher TTA in fruits treated.

4.6 Total Soluble Solids (TSS)

Generally, between the cultivars higher TSS recorded by 'Power' fruits and the lowest by 'Eva' fruits could be as a result of their different genetic make-up which affects their conversion of carbohydrates into sugars. The increase in TSS could be due to excessive moisture loss by 'Power' which as a result increases its concentration and the conversion of carbohydrates to soluble sugars. It was reported by [34] and [35] that, higher TSS in tomato could be as a result of excessive moisture loss which in turn increases concentration as well as the conversion of starch to sugars.

It was observed that, amongst the cultivars and 1-MCP concentration interaction, there was no significant difference in TSS on 'Eva' variety fruits. Nevertheless, higher TSS by 2 ppm of 1-MCP concentration by 'Power' cultivar compared to lower by untreated 'Eva' cultivar might be due to the different cultivars. It was indicated by [12] that, TSS in 1-MCP treated fruits might be higher or lower or the same as non-treated fruits depending on the cultivar, storage condition or storage duration used.

4.7 Moisture Content

The reason for higher moisture content by 'Eva' fruits compared to 'Power' fruits could be as a result of the different nature of tissues in the fruits of the skin wax contents of the cultivars. It could be that, the different cell membrane degradative enzymes, cuticle wax content, their response on membrane integrity and membrane lipid composition are factors that could account for difference in rate of moisture loss amongst different genotypes as reported by [36].

Interactively, the moisture content increased rapidly in control fruits (0 ppm) of both 'Eva' and 'Power' cultivars as the fruits approaches ripening, whereas in 1-MCP treated fruits, moisture content increased gradually on ripening and this could be due to delayed ripening processes caused by reduced ethylene production in the 1-MCP treated fruits. Similar results were observed by [37] for 1-MCP and polyhexamethylene guanidine on the postharvest quality of 'Yelakki' banana.

4.8 Shelf-life

In general, between the cultivars, 'Eva' fruits had a longer shelf-life of 106 days compared to 'Power' fruits which had a shorter shelf-life of 74 days. This could be as a result of the difference in cultivars in which the 'Eva' fruits with firmer fruit skin were able to minimized physical injuries, weight loss and decay.

Interactively, both 'Eva' and 'Power' cultivars treated with higher dose of 1-MCP concentrations had a longer shelf-life compared to the untreated fruits. The longer shelf-life of 122 days by 'Eva' fruits treated with 2 ppm of 1-MCP concentration could be due to the fact that the highest dose of 1-MCP concentration (2 ppm) applied retarded the physiological processes and slowed the ripening of the fruit and greatly reduced the respiratory rate thereby delaying the onset of the climacteric peak during the storage period. According to [38], 1-MCP slows the ripening of fruit, maintained quality and extended the shelf-life of tomato.

The shorter shelf-life of 65 days by the untreated 'Power' fruits (control) could be attributed to the fact that in prolonged periods of storage fruit tissues synthesize more ethylene receptors which in turn increase the respiratory rate at the end of storage and as a result limit the shelf-life of the produce as previously indicated by [14]. The authors explained that fruit tissue synthesize more ethylene receptors which increases the rate of respiration and as a result limits the shelf-life of the produce in prolonged periods of storage.

5. CONCLUSION

'Eva' fruits treated with higher concentrations of 1-MCP (2 ppm) delayed ripening as measured by changes in colour.

Regarding the cultivars, 'Eva' fruits treated with 2 ppm of 1-MCP concentration had firmer fruits compared to untreated 'Power' fruits which were firm. Also, higher cumulative weight loss was recorded by untreated 'Power' fruits and the lowest was by 'Eva' fruits treated with 2 ppm of 1-MCP concentration. Higher moisture content and vitamin C content was recorded by untreated (0 ppm) 'Eva' and 'Power' fruits and the lowest was recorded by 'Power' and 'Eva' fruits treated with 2 ppm of 1-MCP concentration.

'Eva' fruits treated with 2 ppm of 1-MCP concentration had the longest shelf-life while untreated 'Power' fruits had the shortest. Also higher TTA was recorded in 2 ppm of 1-MCP treated 'Power' and 'Eva' fruits and the lowest TTA was recorded by untreated 'Eva' and 'Power' fruits.

The highest TSS was recorded by 'Power' fruits treated with 2 ppm of 1-MCP concentrations and the lowest was recorded by 'Eva' fruits untreated. The results of this research confirmed that the use of 1-MCP have marketable prospect for growers and traders to delay the ripening of green tomatoes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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