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Delaying the Ripening of Banana (*Musa sp.*) cv *Kandula* through the Application of 1-Methylcyclopropane (1-MCP)

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Abstract: Climacteric fruits are treated with 1-Methylcyclopropene (1-MCP) to delay the ripening process, thereby to reduce postharvest losses. This study evaluated the effectiveness of level of 1-MCP on delaying the ripening of *Kandula* banana. Banana hands were exposed to three levels of 1-MCP concentrations (0.5, 1.0 and 2.0 ppm) for 6 h and stored at 14±1^{0}C and 85-90% Relative Humidity (RH). The untreated samples (control) were stored under similar conditions. Peel colour, pulp firmness, total soluble solids (TSS), physiological weight loss and pulp to peel ratio were measured at initial stage and during storage at 4-day intervals. Peel colour of banana samples treated with different levels of 1-MCP remained light green in colour even on day 29 in storage whereas untreated samples fully ripened on day 21 in storage. Further, samples treated with different levels of 1-MCP (0.5, 1.0 and 2.0 ppm) resulted in a least change in a* and b* values compared to the control. Initial a* value (19.63±0.95) of the samples treated with 0.5, 1.0 and 2.0 ppm and the control reduced to -17.63±0.32, -17.30±0.53, -18.47±0.31 and -4.16±0.76 respectively on day 21 in storage. Initial b* value (36.36±1.15) of the samples treated 0.5, 1.0 and 2.0 ppm and the control changed to 37.13±0.32, 34.80±0.00, 36.40±0.35 and 49.26±1.61 respectively on day 21 in storage. Initial pulp firmness (29.20±1.68) of the samples treated with 0.5, 1.0 and 2.0 ppm and the control reduced to 28.10±2.91, 23.90±2.50, 25.20±2.05 and 5.00±0.70 N respectively on day 21 in storage. The TSS of the samples treated with 0.5, 1.0 and 2.0 ppm and the control were 4.80±0.50, 5.20±0.25, and 5.10±0.35 and 15.10±1.00 brix respectively on day 21 in storage. Percentage weight loss of the samples treated with 0.5, 1.0 and 2.0 ppm and the control were 2.08±0.05, 1.93±0.24, 2.04±0.14 and 2.56±1.70% respectively on day 21 in storage. Pulp to peel ratio of the treated samples and the control was not significantly ($p>0.05$) different on day 21 in storage. Treating banana hands with 1- MCP was found to be successful in delaying of ripening. However, as no significant effect of different levelsof 1-MCP on delaying of ripening was evident, 0.5 ppm 1- MCP can be recommended to extend the postharvest life of *Kandula* banana beyond 29 days when stored at 14±1^{0}C.
Keywords: *Kandula* banana; 1-Methylcyclopropane; Delaying of ripening.

1. Introduction

Banana (Musa sp.) is one of the major fruit crops commercially grown in tropics and subtropics that plays a major role in the economy of developing countries. Banana is one of the most important fruits grown island-wide and is available year-round. It is also a widely grown fruit in tropical countries and has the highest consumer demand throughout the world. Annual production is about 45,000 tons and the cultivated land area is about 48,000 ha in Sri Lanka. High economic return attracts rice farmers towards banana cultivation [1]. Out of this total production, about 50% is consumed locally and 30-40% is wasted and about 10% is exported [2]. Postharvest losses in horticultural produce are one of the major problems in present agriculture sector. In the case of fruits, postharvest losses may reduce the availability of fresh produce in the markets, and increase the price gap between the producer and consumer. In banana industry also high postharvest losses is the major problem due to its short shelf life [3]. Banana is a climacteric fruit with soft texture, when ripens. It begins to ripe when expose to stress conditions during handling and transportation. The external appearance of bananas very poor when reaches to consumers due to mechanical damages caused by improper handling. In addition to that, incidences of postharvest diseases such as anthracnose also take place.

There are number of banana cultivars grown in Sri Lanka such as *Ambul*, *Kolikuttu*, *Embun*, *Anamalu*, *Seenikesel*, *Kandula* and *Rathambala*. The *Kandula* cultivar has more consumer preference and a higher price and demand, than other banana cultivars in local market as well as in the international market due to its unique sweet taste, large fruit size and attractive appearance. *Kandula* cultivar has large fruit size leading to high finger

drop when ripens. Therefore, delaying of ripening, until the produce gets delivered to the retail market, could reduce postharvest losses up to a considerable extent. Some of the cultivars are air freighted in limited quantities to Europe, Middle East countries and Maldives [4].

Ripening is initiated by release of endogenous ethylene as banana fruit reaches full maturity or ripening can be induced by using ethylene. Therefore, identification of role of ethylene in fruit ripening and mechanism of fruit ripening are considered powerful tools of the horticultural industry. Modified Atmosphere (MA) packaging is one of the possible technologies that is used to delay the ripening of a wide range of fruits. However, benefits of using MA scrubbers is limited because the increased in-package temperature can cause adverse effects on fruit quality and also increased CO_2 levels or decreased O_2 cause to anaerobic respiration [5]. In recent years, effective agents for blocking the ethylene receptor have been discovered and as a new way of controlling ripening, senescence and other ethylene related responses. 1-methylcyclopropane (1-MCP) is one of the agents which block ethylene receptors and thereby prevents effect of ethylene in plant tissues [6]. 2008). In Sri Lanka research were done to extend the shelf life of *Ambul* [7] and *Kolikuttu* [8] bananas. Ability of 1-MCP to delay ripening of pre-climacteric banana has been demonstrated [9]. A number of factors need to be considered when using 1-MCP such as concentration of 1-MCP, timing, development stage of banana and temperature. All of these factors are significant as the final fruit quality depend on these. The study was conducted to evaluate the effectiveness of 1-MCP on extending the shelf life of banana cultivar *Kandula* at low temperature storage conditions.

2. Material and methods

2.1 Plant material

Matured, green colour *Kandula* banana bunches were purchased from a well maintained commercial orchard at Nachaduwa, Anuradhapura. Immediately after harvesting, the banana bunches were transported carefully to National Institute of Postharvest Management laboratory, Anuradhapura.

2.2 1-Methylcyclopropane treatment

After transportation to the laboratory, all the bunches were dehanded and the banana hands at same maturity stage were selected and damaged fingers were removed. After that, hands were cut into clusters of 3-4 fingers and washed with chlorinated water. After air drying 4% (4g/100ml) alum solution was applied to avoid rotting of the cut surface and the clusters were divided into four lots. Each cluster that comes from same hand was put into each lot and then all four lots represent all the bananas coming from every hand. Three lots of bananas were treated with 0.5 ppm, 1ppm and 2ppm 1-MCP gas concentrations for 6 hours in air tight glass chambers of 95 L capacity and another lot of bananas were put into a chamber without exposing to 1-MCP, considering as the control. Within a lot of bananas were divided into three lots, considering as three replicates per each treatment combination. The concentrations were referred to as empty volume of the chambers. The treatment combinations were selected according to the related literature and previous studies.

1-MCP powder was weighed using an analytical balance and transferred into measuring cylinder using appropriate amount of deionized water for different treatments. The lid of the glass chambers were closed and sealed immediately after putting water to the powder. Calculations of the product weight and water were done according to the manufacturer's instructions. After exposing to 1-MCP, bananas were transferred to plastic crates and kept in the cold room at temperature 14 °C and 85-90% RH.

Plate 1. 1-MCP treatment chamber

2.3 Measurement of physiochemical parameters

Peel colour, pulp to peel ratio, firmness, total soluble solids (TSS) and percentage weight loss of 1-MCP treated *Kandula* banana were measured at initial stage and during the storage period in four day intervals.

2.3.1 Peel colour

The peel colour of banana was measured using a hand held colour difference meter (Model: Minolta, CR 400) and readings were recorded as L*, a*, b* values. The measurements at the stem end, mid region and floral end of each face of the peel were measured and a mean value was obtained from three fruits per treatment.

2.3.2 Determination of Physiological weight loss (PLW)

Weight of fruits at two day intervals using a top loading electrical balance (ARA 20, USA). Same banana samples were used to take weight difference until the end of the experiment and percentage weight loss was measured as follows [10]:

$$Weight\ loss\ (\%) = \frac{(Weight\ of\ the\ previous\ day - Weight\ of\ the\ considering\ day) \times 100}{Weight\ of\ the\ previous\ day}$$

2.3.3 Total soluble solids (TSS)

TSS contents were measured using a hand held pocket refractometer (ATAGO, Model HR-5) and readings were reported as % Brix. Pulp from the middle of a banana was homogenized using a motar and pestle and squeezed through muslin gauze. All refractometer recordings were calibrated to room temperature [11].

2.3.4 Pulp to peel ratio

Pulp to peel ratio of banana fruit samples were determined by dividing the weight of pulp by peel weight [10].

$$Ratio = \frac{Weight\ of\ pulp}{Weight\ of\ peel}$$

2.3.5 Pulp firmness

Firmness was measured using fruit firmness tester (Model CS 1-2, ITALY). Penetrometer mounted on a drill press equipped with an 8 mm diameter probe. Firmness was measured in the proximal, middle and distal portion of peeled bananas and the average was taken. Results were expressed in N.

2.4 Statistical analysis

The experimental design was Complete Randomized Design with three treatments and control. All the experiment data were analyzed using ANOVA in SAS package 9.0 and mean separation was done using Duncan's multiple range test.

3. Results and Discussion

3.1 Effect of 1-MCP on ripening of banana fruit

The *Kandula* banana samples treated with different levels of 1-MCP (0.5, 1 and 2 ppm) resulted a least change in ripening compared to untreated banana samples on 21 days of storage. The control samples reached to fully ripen stage after 21 days while the 1- MCP treated samples were in light green stage after 29 days at 14 ± 1^0C and 85-90% RH. 1-MCP can extend the green life or shelf life of bananas [12]. This study proven that 1-MCP has the ability of delaying the ripening of *Kandula* banana (*Musa sp*.) grown in Sri Lanka. A variety of physical and chemical properties were measured to come into that conclusion. It showed that, there is a significant effect of 1-MCP on delaying of banana ripening and there is no significant difference between the concentrations at 0.05 significant level.

Plate 2. Initial stage mature green banana

Plate 3. Fully ripen untreated banana at 21 day in storage

Plate 4. Light green colour 0.5ppm1-MCP treated banana at 29 days in storage

Plate 5. Light green colour 1.0 ppm 1-MCP treated banana at 29 days in storage

Plate 6. Light green colour 2.0 ppm 1-MCP treated banana at 29 days in storage

3.2 Effect of 1-MCP on peel colour

Fig. 1 shows the change in a* value of banana peel. A positive (a*) values corresponding to the degree of redness, while a* negative value corresponding to the degree of greenness. The initial a* values of the untreated (control) samples increased rapidly during 21 days in storage, while the samples treated with 1- MCP showed a least change in values even in day 29 in storage. Control samples reached fully yellow colour after 21 day of storage, whereas 1-MCP treated banana samples showed higher a* values indicating they were still in unripen stage after 29 days in storage. It was statistically proven that, a* value of the control and 1-MCP treated samples were significantly ($p<0.05$) different at 21 days in storage.

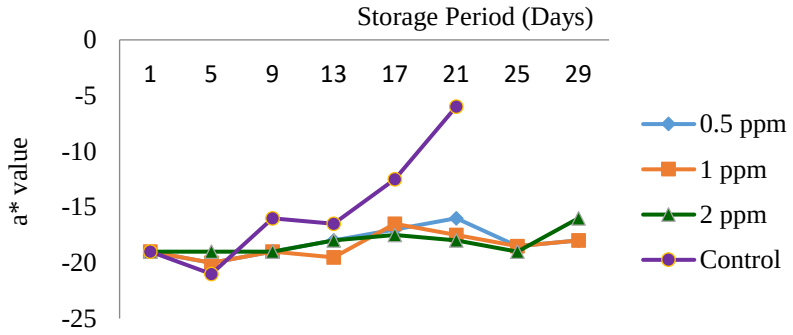

Figure 1. Effect of 1-MCP on change of a* value of *Kandula* banana peel

As shown in fig. 2, the positive values (b*) represents the degree of yellowness and negative one represents the blueness. The initial b* values of the untreated (control) samples increased rapidly during 21 days in storage, while the samples treated with 1-MCP showed a least change in b* values even in day 29 in storage (Fig. 2). Control samples reached fully yellow colour after 21 day of storage, whereas 1-MCP treated banana samples showed lower b* values indicating they were still in unripen stage after 29 days in storage. It was statistically proven that, the b* value of the control and 1-MCP treated samples were significantly ($p<0.05$) different at 21 days in storage.

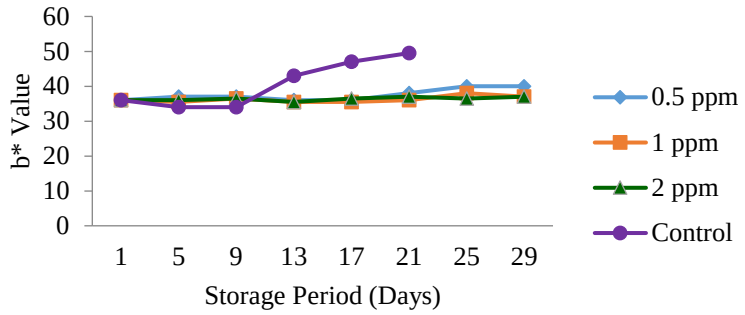

Figure 2. Effect of 1-MCP on change of b* value of *Kandula* banana peel

Peel colour is an important criterion of postharvest quality and consumer acceptability, especially with respect to bananas. Among the measures that were used to determine the ripeness of banana, change of peel colour is important, because it is a non- destructive, visual observation and is the simplest. The peel colour development of 1- MCP treated *Kandula* banana was slower than untreated banana whereas the 1-MCP concentrations did not significantly affected the peel colour development. Fruit treated with1 1-MCP retained lower a* and b* values throughout the storage time indicating 'greener' fruit. Boggala et al. (2014) [13] observed similar results for 1-MCP treated tomatoes. The 1-MCP treatment of 0.5 ppm, 1 ppm and 2 ppm exhibited a coincided development of peel colour from green to yellow, indicating that ripening takes place at the same time in three of the treatments. This behaviour was common in the gradual change of pulp firmness, total soluble solid content and percentage weight loss over time. Harris et al. (2000) [14] concluded that the exposure to 1-MCP delayed changes in skin colour and flesh softening of bananas and the magnitude of this effect was dependent on concentration.

3.3 Effect of 1-MCP concentrations on pulp firmness

The effect of 1-MCP on pulp firmness of treated bananas are shown in fig 3. Results indicated that there was a sharp decline in pulp firmness of control samples during first 17 days after treatment. At 21 day after treatment, control fruits reached fully ripen stage while the banana treated with 1-MCP having significantly higher pulp firmness, indicating they are still in the unripen stage. It was statistically proven that there is a significant effect of 1-MCP on pulp firmness during storage after treatment ($p<0.05$). Treatments with different concentrations of 1-MCP showed comparatively slower decline of pulp firmness. Mean pulp firmness of 1-MCP treated bananas was not significantly different. The ripening of fruits is characterized by softening of pulp due to cell wall digestion by pectinesterase, polygalacturonase and other enzymes. And also softening is accompanied by a reduction in the size of hemicelluloses, loss of galactose side chains and solubilization and depolymerization of pectin [15].

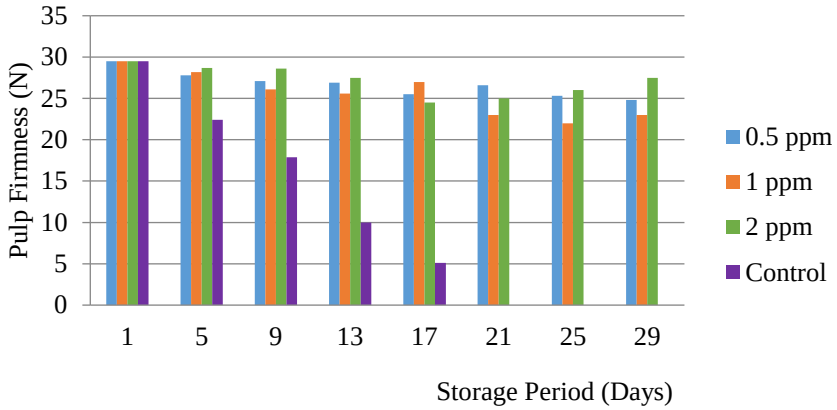

Figure 3. Effect of 1-MCP concentrations on changes of pulp firmness of *Kandula* banana

Changing of pulp firmness of 1-MCP treated samples were slower compared to control, it showed a rapid decline in storage during 21 days. No significant difference among the 1-MCP concentrations were evident until 29 days in storage and the firmness value were significantly higher compared to control. It indicates that treated samples were still in unripen stage. Structural changes in pectin, hemicellulose and cellulose together are considered to be

responsible for the alteration of cell wall structure during ripening related loss of firmness. These changes include not only solubilisation and depolymerisation of the polysaccharides but also rearrangements of their associations [16].

3.4 Effect of 1-MCP concentration on total soluble solid content (TSS)

A higher rate of increment in total soluble solid content was observed in control until 17 days after treatment (Fig 4). There was significantly lower total soluble solid content in 1-MCP treated *Kandula* banana than control treatment ($p<0.05$), indicating that control is at the fully ripen stage and 1-MCP treated banana haven't reached to that stage at twenty first day after treatment. There was no any significant effect of 1-MCP concentration in total soluble solid content. Almost complete hydrolysis of starch occurs in banana during ripening and it shows an increase of soluble sugars such as glucose, sucrose and fructose. Ripening is evidenced by the sudden increment of total soluble solid content of control treatment and significantly lower amount in 1-MCP treated banana which are still in the unripen stage. The 1-MCP treatment combinations showed significantly slower increment of total soluble solid content than the control [10].

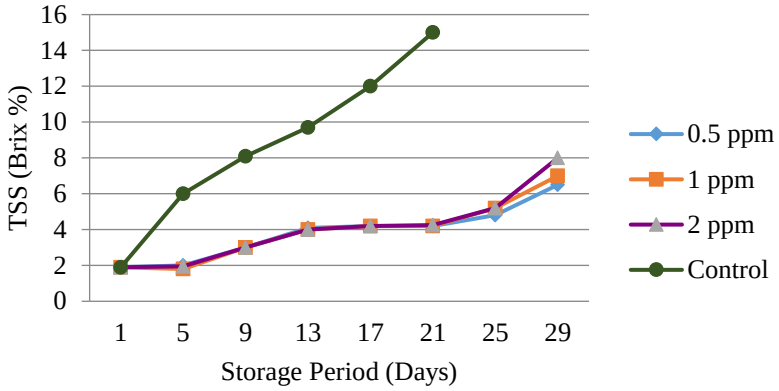

Figure 4. Effect of 1-MCP concentrations on change of TSS content of *Kandula* banana

3.5 Effect of 1-MCP on physiological weight loss

The physiological weight loss of untreated *Kandula* banana was higher compared to samples treated with 1-MCP during storage in 21 days (Table 1). It was statistically proven with 5% significant level. Physiological weight loss of untreated samples did not show much different with time. There was no significant difference among different concentrations of 1-MCP. The weight loss is considered to be the major determinant of storage life and postharvest quality of banana. It is commonly believed that the weight loss from fresh fruits and vegetables is through the peel by vapour pressure, which can cause flesh softening, fruit ripening, and senescence by metabolic reactions. However, the respiration process also causes a weight reduction because a carbon atom is lost from the fruit in each cycle [15]. But in the cold storage, RH is high therefore evaporation loss is lower, and respiration may cause to the weight loss. Other studies have reported that the 1-MCP application produced a decrease in weight loss during storage for Chinese chives, plums and tomatoes [17]. Fruit size also affect the percentage weight loss of banana. Percentage weight loss of small fruit is higher than the larger one [10].

Table 1. Effect of 1-MCP application on changes of percentage weight loss of *Kandula* banana

Storage Period (Days)	Physiological weight loss (%)			
	0.5 ppm	1 ppm	2 ppm	Control
5	2.06 ± 0.06^{b}	2.12 ± 0.31^{b}	2.17 ± 0.17^{b}	2.32 ± 0.08^{a}
9	2.09 ± 0.04^{b}	2.11 ± 0.06^{b}	2.01 ± 0.13^{b}	2.23 ± 0.13^{a}
13	2.03 ± 0.12^{b}	2.03 ± 0.41^{b}	2.01 ± 0.34^{b}	2.18 ± 0.06^{a}
17	2.03 ± 0.11^{b}	2.08 ± 0.05^{b}	2.03 ± 0.15^{b}	2.23 ± 0.09^{a}
21	2.08 ± 0.06^{b}	1.93 ± 0.21^{b}	2.04 ± 0.15^{b}	2.25 ± 0.15^{a}

3.6 Effect of 1-MCP on pulp to peel ratio

Pulp to peel ratio of untreated samples showed small increase during storage of 21 days (Table 2). But there was no significant ($p>0.05$) difference observed between all the treatments including control. Banana samples treated with 1-MCP also showed a slight increase in pulp to peel ratio during storage of 21 days, and no significant different was observed among different concentrations of 1-MCP at 5% significant level of DMRT. The pulp to peel ratio of all treatments were not significantly different. It may be due to the low temperature and high RH

storage condition. High RH reduces the loss of weight due to evaporation. The pulp to peel ratio of banana fruits increase as the ripening advances due to conversion of starch into sugars and the loss of moisture from the peel through transpiration [18].

Table 2. Effect of 1-MCP concentrations on changes of pulp to peel ratio of *Kandula* banana

Storage Period (Days)	Percentage weight loss			
	0.5 ppm	1 ppm	2 ppm	Control
1	1.81±0.13[a]	1.81±0.13[a]	1.81±0.13[a]	1.81±0.13[a]
5	1.73±0.13[a]	1.81±0.14[a]	1.78±0.09[a]	1.70±0.15[a]
9	1.82±0.18[a]	1.69±0.09[a]	1.69±0.03[a]	1.81±0.03[a]
13	1.84±0.08[a]	1.76±0.17[a]	1.89±0.02[a]	1.99±0.03[a]
17	1.97±0.10[a]	1.82±0.10[a]	2.07±0.36[a]	1.93±0.11[a]
21	2.10±0.05[a]	2.14±0.10[a]	2.08±0.06[a]	2.13±0.10[a]

3.7 Effect of 1-MCP on shelf life

There was a significant difference between shelf life of untreated *Kandula* banana and 1-MCP treated bananas. Untreated banana had 21 days of shelf life and reached fully ripen stage whereas 1-MCP treated banana were in light green colour stage even on day 29 in storage. The shelf life of treated banana may go beyond 29 days. There was no difference in the shelf life of different concentrations of 1-MCP observed. The shelf life of the control fruit was 21 days in 14^0 C whereas the banana treated with 0.5, 1.0 and 2.0 ppm of 1-MCP could be stored beyond 29 days in similar conditions as it remained in light green colour at day 29 in storage. Blankenship (2001) [19] stated that, the maturity of the plant produce would affect the results and if fruit is at late maturity, 1- MCP will not work well. Bagnato et al. (2003) [11] reported that, 1-Methycyclopropene is a promising postharvest treatment for the extension of banana shelf-life to more than 6 days at 20^0 C when applied after ripening initiation. Quality of banana flesh and visual appearance was not affected by 1-MCP treatments of ≤300 nL L-1. However, the 1-MCP concentration used is critical, as low concentrations (≤ 3 nL L-1) did not extend banana shelf-life and high concentrations (30 µL L-1) caused fruit to be unacceptable for consumption. But at temperature 14^0C low concentrations of 1-MCP delayed the ripening to a considerable extend and visual quality of fruit also in an acceptable level. During 29 day storage of 1-MCP treated bananas, there was no significant difference was observed in any physiochemical parameters. It may be due to the blocking of all ethylene receptors of banana successfully in same way by all the concentrations used.

4. Conclusion

1-Methycyclopropene is a promising postharvest treatment for the extension of banana shelf-life to more than 29 days at 14^0C when applied at mature green stage before ripening initiation. Quality of banana flesh and visual appearance was not affected by 1-MCP treatments of 0.5, 1.0 and 2.0 ppm. Even though treating of banana hands with 1-MCP was found to be successful, as no significant effect of different concentrations of 1-MCP on delaying of ripening was evident, 0.5 ppm 1-MCP can be recommended to extend the postharvest life of *Kandula* banana beyond 29 days when stored at 14±1 ^{0}C.

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