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Effect of 1-Methylcyclopropene (1-MCP) on Quality and Shelf-Life of Banana Fruits

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Abstract: The effect of 1-Methylcyclopropene (1-MCP) on quality and shelf–life of 'Grand Nain' banana fruits was evaluated. 1-Methylcyclopropene at 62.5, 125 and 250 ppb delayed fruit ripening, maintained quality and extended shelf-life of banana fruits. The higher the concentration of 1-MCP, the more was the effect. 1-Methylcyclopropene significantly delayed the onset of the climacteric peak. The untreated fruits reached the climacteric peak after 8 days at 18± 1°C and 85% - 90% relative humidity. Treatment with 1-MCP at 62.5, 125 and 250 ppb significantly delayed the onset of the climacteric peak by 12, 16 and 20 days, respectively, compared with the untreated fruits. The effect of 1-MCP was also reflected similarly in retarded peel colour development and total soluble solids (TSS) accumulation, reduced fruit flesh softening and weight loss, and retained ascorbic acid content during storage of banana fruits.

Key words: Banana fruit; 1-MCP; quality; shelf-life

INTRODUCTION

Banana (*Musa,* AAA-Group) is the most popular fruit crop in Sudan for its nutritive value, low price and availability all year round. It is grown in almost every state, with an annual production of 540 thousand metric tons (AOAD 2008).

Banana is a typical climacteric fruit that exhibits a characteristic rise in ethylene production and respiration rate during ripening (Kader 2002). The high rate of respiration and ethylene production, which is usually associated with short shelf-life, soft texture and high moisture content, makes banana a very perishable fruit that requires absolute care during handling and transportation (Wills *et al.* 1998). The fruits are usually harvested green at about 75% maturity, transported to distant markets and are ripened afterwards. During transit, they should remain green and firm for one to two weeks, depending on market distance (Kader 2002).

The green-life of banana can be extended by transporting them under optimum conditions of temperature, relative humidity and composition of the atmosphere, elimination of ethylene and use of ripening retardants (Kader 2002). Recently, 1-methylcyclopropene (1-MCP) has been employed to increase the shelf-life of some horticultural commodities. By binding to the ethylene receptors, 1-MCP acts as an efficient ethylene antagonist and its effects can persist for a long time (Sisler *et al.* 2003). It can, therefore, slow down the ripening process as well as senescence of the fruit (Sisler and Serek 1997). 1-MCP is being described as a breakthrough shipping and storage technology that can maintain the fresh-picked' quality of ethylene sensitive commodities (Bates and Warner 2001).

1-Methylcyclopropene (1-MCP) is marketed as 'SmartFresh' from AgroFresh and distributed commercially as a cyclodextrin-bound formulation. When warm water or diluted base is added, the sugar dissolves and 1-MCP is released as a gas into the surrounding environment (Daly and Kourelis 2001). 1-Methylcyclopropene delayed fruit ripening, maintained quality and extended shelf-life of apple (Beaudry 2001), avocado (Woolf *et al.* 2005), banana (Golding *et al.* 1998), mango (Hofman *et al.* 2001), plum (Candan *et al.* 2006) and tomato (Huber *et al.* 2003).

The response of the fruit to 1-MCP depends upon a number of variables, including: fruit kind, cultivar and maturity, gas concentration, application temperature, duration and technique, and storage environment (Beaudry 2001; Pelayo et *al.* 2003). Bananas treated with 1-MCP and kept in polyethylene bags eventually ripen, indicating that bananas might make new receptors in this situation (Jiang *et al.* 1999). However, bananas treated with 1-MCP may also stay green or will ripen with an uneven colour (Harris *et al* 2000). Lack of ripening probably indicates that receptors were not regenerated.

This study was carried out to evaluate the effect of 1-MCP on quality and shelf-life of 'Grand Nain' banana fruits in Sudan.

MATERIALS AND METHODS

'Grand Nain' banana fruits were obtained from a private orchard in Sinja area, 400 km south of Khartoum. Fruits were harvested at the 'full three quarters' mature-green stage. The fruits were selected for uniformity of size, colour and freedom from blemishes and defects. The banana bunches were transported by truck to the laboratory, dehanded and divided into fingers. The fruits were washed with tap water to remove latex and dust, treated with 10% sodium hypochlorite (Clorox, 52g Cl/L), as a disinfectant, and air-dried.

The fruits were distributed among the four treatments (50 fruits each) in a completely randomized design with four replications. Fruits were treated with 0 (control), 62.5, 125 and 250 $nl.L^{-1}$(ppb) 1-MCP (SmartFresh, 0.14%) for 24 hours at 18±1˚C in hermetically sealed 20 liters plastic chambers, according to the manufacturer recommendations. Information provided by AgroFresh indicates that 1.6 g of SmartFresh powder releases 1 ml of gas at 25˚C (Blankenship and Dole, 2003). The required concentrations of 1-MCP were obtained by adding 25 ml of warm distilled water at 50˚C to the appropriate amounts of 1-MCP (SmartFresh, 0.14%) powder, calculated according to the free space volume, in 100 ml flasks. After complete dissolution of 1-MCP powder, the flasks were placed and opened in the treatment chambers which were immediately sealed to avoid gas loss. Control fruits were maintained in identical containers, but without 1-MCP. Following the 24 hours treatment time, fruits were placed in carton boxes (50 x 30 x 20 cm) lined with perforated polyethylene films and stored at 18±1˚C and 85-90% relative humidity for about 30 days.

Respiration rate was determined every day during the ripening period in 15 fruits in each replication in a flowing system by the total absorption method (Mohamed-Nour and Abu-Goukh 2010) and expressed in mg

CO_2/kg-hr. Peel colour was determined daily on the same 15 fruits used for determination of respiration. The banana colour chart developed by
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Chiquita of United Brands Company was used in estimating colour score (Chiquita Brand Inc. 1975).

Weight loss was determined on the same fruits used for determination of respiration rate and peel colour. A digital sensitive balance was used to determine fruit weight. Weight loss (%) in fruits was calculated according to the formula: $W_1 = \{(W_0 - W_t) / W_0\} \times 100$, where W_1 is the percentage weight loss, W_0 is the initial weight of fruits; W_t is the weight of fruits at the designated time. Flesh firmness was determined every two days on three fruits picked randomly, other than those used for determination of respiration, peel colour and weight loss. Magness and Taylor firmness tester (D. Ballauf Meg. Co.) equipped with an 8 mm-diameter plunger tip was used. Two readings were taken from opposite sides of each fruit after the peel was removed. Flesh firmness was expressed in kilograms per square centimeter. Total soluble solids (TSS) were measured directly from the fruit pulp on the same fruits used for determination of flesh firmness at two-day intervals during storage, using Kruss hand refractometer (model HRN-32). Two readings were taken from each fruit and mean values were calculated and corrected according to the refractometer chart.

Thirty grams of fruit pulp from each replicate were homogenized in100 mL of distilled water for one minute in a Sanyo Solid State blender (model SM 228P) and then centrifuged at 10,000 rpm for 10 minutes using a Gallenkamp portable centrifuge (CF 400). The volume of the supernatant, which constitutes the pulp extract, was determined. Ascorbic acid was determined in fruit pulp extracts every two days on the same fruits used for flesh firmness and TSS, using the 2,6- dichlorophenol-indophenol titration method of Ruck (1963). Ascorbic acid was expressed in milligrams per 100 grams fresh weight.

Analysis of variance (ANOVA), followed by fisher's protected LSD test with a significance level of $P \leq 0.05$ were performed on the data (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

1-Methylcyclopropene (1-MCP) significantly delayed fruit ripening, maintained quality and extended shelf-life of banana fruits. Similar results were reported for apple (Beaudry 2001), avocado (Woolf *et al*. 2005), banana (Golding *et al*. 1998; Pelayo *et al*. 2003), mango (Hofman *et al.* 2001), Plum (Candan *et al*. 2006) and tomato (Moretti *et al*. 2002). 1-Methylcyclopropene which inhibits ethylene action by blocking ethylene receptors (Candan *et al*. 2006), acts as an efficient ethylene antagonist and its effect can persist for long time (Sisler *et al*. 2003). It can therefore, slow down the ripening process as well as senescence of the fruit (Sisler and Serek 1997).

The 1-MCP treated fruits after delayed ripening, ripened normally without adverse effect on quality, which indicated that new receptors were formed. This agrees with Jiang *et al.* (1999), but disagrees with Harris *et al.* (2000), who reported that bananas treated with 1-MCP stayed green or ripened with an uneven colour, indicating that receptors were not regenerated. The effect of 1-MCP in delaying fruit ripening and extension of shelf-life of banana fruits was reflected in changes in respiration rate, peel colour, flesh firmness, total soluble solids (TSS), weight loss, and ascorbic acid content of the fruits.

Effect on respiration rate

The respiration curves, in all treatments, exhibited a typical climacteric pattern with a climacteric peak at 41.8 mg CO_2/kg-hr in the untreated fruits (Fig.1-A). 1-Methylcyclopropene treatment slightly decreased the climacteric peak. The untreated fruits, reached the climacteric peak after 8 days at 18±1°C and 85%-90% RH. 1-Methylcyclopropene treatment significantly delayed the onset of the climacteric peak. Fruits treated with 1-MCP at 62.5, 125 and 250 ppb reached the climacteric peak 12, 16 and 20 days later, respectively, compared with the untreated fruits (Fig.1-A). This agrees with previous reports that 1-MCP reduces or delays the increase in respiration rate (Tian *et al*. 2000). In mature-green banana fruits, treated with 1-MCP, the peaks of respiration rate and ethylene production were significantly delayed, but the peak height was not reduced (Jiang *et al*. 2004). Respiration was suppressed in propylene-

treated bananas subsequently gassed with 1-MCP (Golding *et al.* 1998). In strawberry 1-MCP inhibited the ethylene-induced respiratory increase in early-harvested fruits, but not late-harvested fruits (Tian *et al.* 2000). Respiration was also inhibited in apples (Fan *et al.* 1999).
Respiratory increase in avocado was delayed by about 6 days and reduced in magnitude by about 40% with 1-MCP treatment (Hofman *et al.* 2001). Similar results were reported in apricot (Fan *et al.* 2000), guava (Bassetto *et al.* 2005) and lime (Jomori *et al.* 2003).

Effect on peel colour
Peel colour score progressively increased during storage of banana fruits regardless of the treatment. The untreated fruits reached the full yellow stage (colour score 7) after 12 days (Fig. 1-B). 1-Methylcyclopropene significantly delayed the development of peel colour. Fruits treated with 1-MCP at 62.5, 125 and 250 ppb reached the full yellow colour (colour score 7) after 13, 17 and 20 days later, compared with the untreated fruits, respectively (Fig. 1-B). 1-Methylcyclopropene prevented or delayed chlorophyll degradation and various types of colour changes in a wide range of crop species. Degreening of 'Fuji' apples was inhibited by 1-MCP and 1-MCP-treated 'Red Chief' apples had a greener background colour than untreated fruits (Fan and Mattheis 1999). In apricots, 1-MCP-treated fruits were greener and exhibited less colour change than untreated fruits (Fan *et al.* 2000). This was also found to be true in peach (Kluge and Jacomino 2002), avocado (Jeong *et al.* 2001), guava (Bassetto *et al.* 2005), orange (Porat *et al.* 1999), lime (Jomori *et al.* 2003) and tomato (Huber *et al.* 2003).

When bananas treated with 1-MCP were subsequently treated with propylene, degreening was delayed and the fruits had a patchy, uneven colour (Golding *et al.* 1998). 1-Methylcyclopropene delayed chlorophyll degradation in coriander when ethylene was present (Jiang *et al.* 2002).

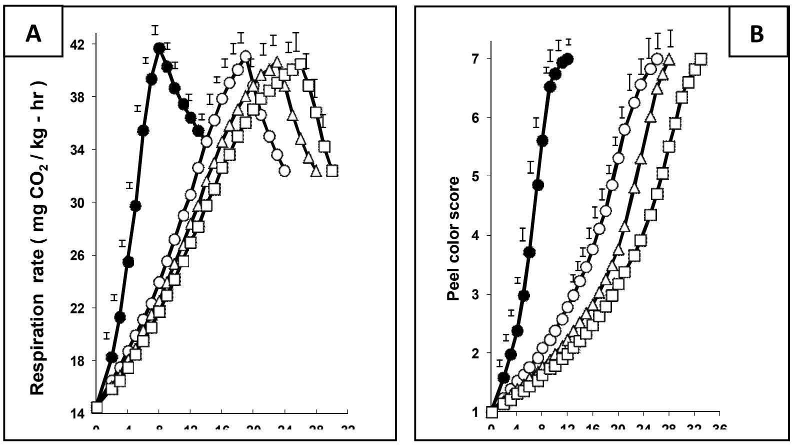

Fig. 1. Changes in respiration rate [A] and peel colour [B] during storage of 'Grand Nain' banana fruits treated with 1-MCP at 62.5 ppb (○), 125 ppb (Δ) and 250 ppb (□), compared with untreated fruits (●) at 18±1˚C and 85% - 90 % relative humidity. Vertical bars represent LSD (5 %).

Effect on flesh firmness

Fruit flesh firmness progressively declined during the storage of banana fruits. In the untreated fruits, flesh firmness dropped from 2.13 kg/cm^2 to 0.1 kg/cm^2 after 12 days in storage (Fig. 2-A). 1-Methylcyclopropene treatment significantly delayed the drop in flesh firmness during the storage of banana fruits and the treated fruits were more firm than the control at any time during the storage period. The treated fruits with 1-MCP at 62.5, 125 and 250 ppb reached the final soft stage (0.1 kg/cm^2) after 12, 16 and 18 days later, respectively, compared with the control (Fig. 2-A). Application of 1-MCP retarded softening in banana (Jiang *et al.* 1999), apple (Fan *et al.* 1999), peach (Kluge and Jacomino 2002), apricot (Fan *et al.* 2000), mango, papaya, custard apple (Hofman *et al.* 2001) and guava (Bassetto *et al.* 2005). Flesh firmness was delayed without negative impacts on the quantitative or qualitative aroma composition of bananas (Pelayo *et al.* 2003).

More detailed examinations of softening showed that polygalacturonase (PG) and cellulase activities were lowered by 1-MCP, however, activities of both enzymes were present and avocado fruits ripened and softened normally (Feng *et al*. 2000). Jeong *et al*. (2001) found that PG activity was completely suppressed for up to 10 days, indicating that softening can occur without PG activity in avocado. Pectinesterase (PE) activity was delayed in 1-MCP-treated avocado fruits, compared with the control, but followed a similar pattern (Jeong et *al*. 2001). These changes in flesh firmness determine shelf-life and quality of the commodity. Control of texture is a major objective in modern food technology. From horticultural perspective, tissue firmness is an important quality attribute and the rate of firmness loss during ripening may influence not only fruit quality but also its storage life (Wills *et al.* 1998).

Effect on total soluble solids

Total soluble solids (TSS) progressively increased during storage of banana fruits. The maximum TSS value reached by the untreated fruits was 22.5% after 12 days (Fig. 2-B). 1-Methylcyclopropene treatment significantly delayed the accumulation of TSS during storage of banana fruits. Bananas treated with 1-MCP at 62.5, 125 and 250 ppb, reached the maximum TSS value after 12, 16 and 18 days later, respectively, compared with the control. Soluble solids were higher in 1-MCP-treated apple (Fan *et al*., 1999) and papaya (Hofman *et al*. 2001). However, soluble solids were reduced in 1-MCP-treated strawberries regardless of the presence or absence of exogenous ethylene (Tian *et al*. 2000). Fan *et al*. (1999) showed that soluble solids were higher in 1-MCP-treated 'Delicious' and 'Fuji' apples, but were not affected in 'Ginger Gold','Gala' and 'Jonagold' apples. Soluble solids were unaffected by 1-MCP in orange (Porat *et al.* 1999), custard apple and mango (Hofman *et al*. 2001).

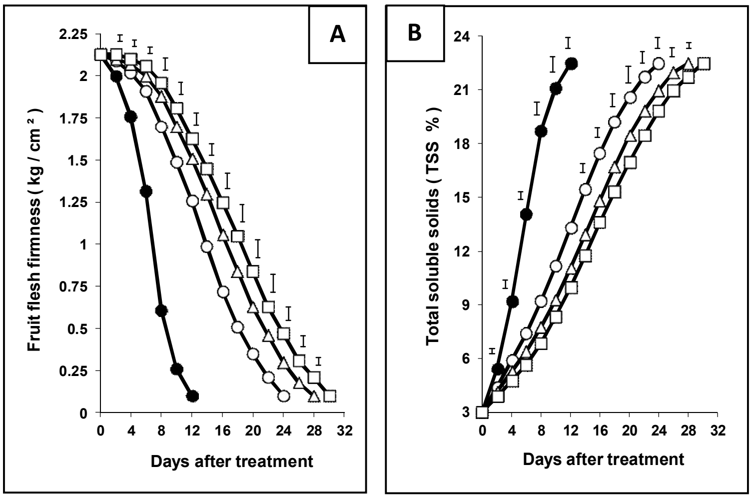

Fig. 2. Changes in fruit flesh firmness [A] and total soluble solids [B] during storage of 'Grand Nain' banana fruits treated with 1-MCP at 62.5 ppb (○), 125 ppb (Δ) and 250 ppb (□), compared with untreated fruits (●) at 18±1˚C and 85% - 90 % relative humidity. Vertical bars represent LSD (5 %).

Effect on weight loss

Weight loss progressively increased during storage of banana fruits regardless of treatment (Fig. 3-A). Weight loss was followed until the fruits reached the full yellow stage (colour score 7). At that stage, the control fruits packed in lined cartons boxes, without 1-MCP, reached the highest weight loss percentage of 23.1% after 14 days. 1-Methylcyclopropene significantly reduced weight loss at all concentrations. Weight loss was delayed in fruits treated with 1-MCP during storage of banana fruits. The fruits treated with 62.5, 125 and 250 ppb 1-MCP reached the highest weight loss percentage of 23.1% after 24, 28 and 31 days, respectively, compared with 14 days in the untreated fruits (Fig. 3-A). This is in line with previous reports that 1-MCP reduced fruit weight loss in plum (Martinez -Romero *et al.* 2003) and avocado (Jeong *et al.* 2001). On the other hand, 1-MCP did not affect weight loss in orange (Porat *et al.* 1999) and mango (Hofman *et al.* 2001).

Effect on ascorbic acid content

Ascorbic acid content showed continuous decline during storage of banana fruits in all treatments. It decreased from 19.4 to 9.1 mg/100g fresh weight in the untreated fruits (Fig. 3-B). Ascorbic acid retained after 12 days of storage in the untreated fruits was 46.3% of the initial amount, while it was 58.5%, 63.8% and 67.6% in fruits treated with 1-MCP at 62.5, 125 and 250 ppb, respectively (Fig. 3-B). 1-Methylcyclopropene resulted in higher ascorbic acid retention. Ascorbic acid was 24.7%, 35.9% and 44.1% higher in the fruits treated with 62.5, 125 and 250 ppb 1-MCP, respectively, compared with the untreated fruits. These fruits reached the lowest ascorbic acid content of 9.1 mg/100g, after 12, 16 and 18 days later, respectively, compared with the control (Fig. 3-B). This is in agreement with the reports that 1-MCP decreases or delays loss of ascorbic acid in pineapple (Buda and Joyce, 2003) and lettuce (Wills *et al.* 2002). Ascorbic acid content was not influenced by 1- MCP in guava fruits (Bassetto *et al.* 2005).

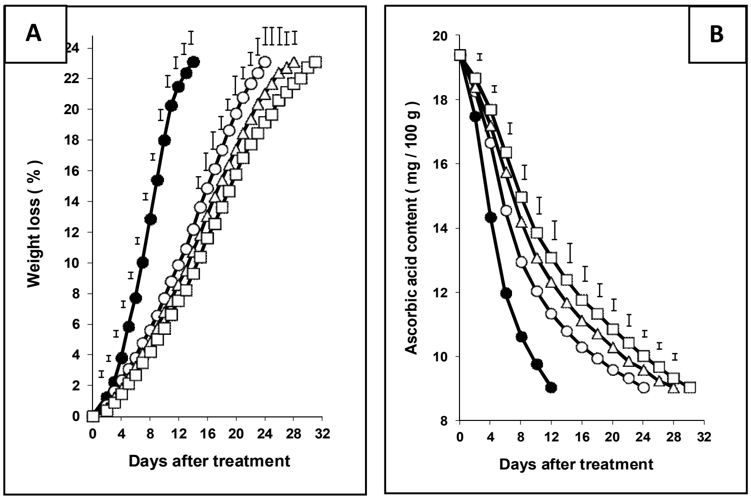

Fig. 3. Changes in weight loss [A] and ascorbic acid content [B] during storage of 'Grand Nain' banana fruits treated with 1-MCP at 62.5 ppb (○), 125 ppb (Δ) and 250 ppb (□), compared with untreated fruits (●) at 18±1˚C and 85% - 90 % relative humidity. Vertical bars represent LSD (5 %).

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تأثير الميثايل سايكلوبروبين (1-MCP) على جودة وطول العمر التسويقي لثمار الموز

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المُستخلص: الهدف من إجراء هذه الدراسة هو تقييم تأثير الميثايل سايكلوبروبين (1-MCP) على جودة وطول العمر التسويقي لثمار الموز من صنف "قراند نين" . أستخدم الميثايل سايكلوبروبين المسوق في شكل "إسمارت فريش" (SmartFresh) مــن شــركة "أقروفريش" (AgroFresh) والموزع تجارياً في شكل تركيبة من "السايكلودكسترن" (Cyclodextrin) . عندما أضيف الماء الدافي لتركيبة "السايكلودكسترن" تم إفراز غاز-1 MCP في الجو المحيط . عوملت الثمار بتركيز صفر (شاهد) و 62.5 و 125 و250 جزء في البليون ميثايل سايكلوبروبين (1-MCP) (SmartFresh, 0.14 %) لمدة 24 ساعة في حاويات بلاستيكية محكمة الإغلاق سعة 20 لتراً ، حسب توصيات الشركة المنتجة ، ثم خزنت الثمار في درجة حرارة 18 ± 1°م ورطوبة نسبية 85%–90% . أدت المعاملة بالميثايل سايكلوبروبين (1-MCP) إلى تأخير نضج الثمار والمحافظة على الجودة وإطالة العمر التسويقي لثمار الموز ، وكان التركيز الأعلى أكثر فعالية . أدت المعاملة بالميثايل سايكلوبروبين (1-MCP) معنوياً لتأخير وصول الثمار إلى ذروة التنفس. فبينما وصلت الثمار غير المعاملة إلى ذروة التنفس في 8 أيام ، فقد تأخر معنوياً وصول الثمار المعاملة بالميثايل سايكلوبروبين (1-MCP) بتركيز 62.5 و 125 و 250 جزء في البليون إلى ذروة التنفس في 12 و 16 و 20 يوماً على التوالي ، مقارنة بالثمار غير المعاملة . كما إنعكس تأثير المعاملة وبنفس المستوى على تأخير تلون القشرة الخارجية للثمار وتراكم المواد الصلبة الكلية الذائبة فيها ، وتقليل ليونة لب الثمار وفقد الوزن ، والمحافظة على محتوى حمض الأسكوربيك في الثمار أثناء فترة تخزينها .