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INFLUENCE OF POST-HARVEST APPLICATION OF *Stenotrophomonas rhizophila* ON QUALITY OF MANGO CV. BARI AAM-3

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Abstract

The study was conducted at the Postharvest and Plant Biotechnology Laboratory,of Patuakhali Science and Technology University, Patuakhali, Bangladesh during the period from July to December 2018 to study the biocontrol performances of selected antagonistic bacteria *Stenotrophomonas rhizophila* strain PSTU-Hort-14 on BARI Aam-3**.** All the treatments were arranged in a completely randomized design (CRD) with five replications and repeated twice. The bacterial strain under study was found highly compatible with 20% lemongrass extract and 2% sodium bicarbonate (SBC) or mixture of both which reduced 96.5% of disease over control in naturally infected fruits at the end of 14 days of storage at 12±1ºC and 90±5% RH. The combined treatments of Stenotrophomonas rhizophila-lemongrass extract-SBC showed reduced weight loss by more than 25% compared to the control at 12±1ºC and 90±5% RH. The shelf life was thus extended by 15 days compared to control at 12±1ºC and 90±5% RH. Finally, it was clear that the strain Stenotrophomonas rhizophila strain PSTU-Hort-14 was effective when incorporated with 2% SBC and 20% lemongrass extract to control *C. gloeosporioides* as well as improve the postharvest quality of BARI Aam-3 during cold storage.

Keywords: BARI Aam-3, Mango, Quality, *Stenotrophomonas rhizophila*,, Storability

Introduction

Postharvest pathogens caused significant losses in fruits and they are normally controlled by using synthetic fungicides. Biological control has been developed as an alternative to synthetic fungicide treatment and considerable success has been achieved upon utilizing antagonistic microorganisms to control both pre harvest and postharvest diseases (Janisiewicz and Korsten, 2002). Presently, Edible coatings are traditionally used to improve food appearance and conservation.They act as barriers during processing, handling and storage. They are not solely retard food deterioration and enhancing its quality, but are also safe due to their natural biocide activities or to the incorporation of antimicrobial compounds. Different compounds have been used as

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edible coatings to prevent commodity weight loss, including wax, milk proteins, celluloses, lipids, starch, zein, and alginate (Cha and Chinnan, 2004). Some of the recent findings was the used of chitosan which reduced weight loss and softening with extended shelf life of mango (Ali *et al*., 2011). In addition, edible coatings based on gum arabic alone or in combination with essential oils treatments reduced postharvest anthracnose and delayed ripening of mango and banana (Maqbool *et al.*, 2011).

Presently, there is an increasing interest in the use of lemongrass extract (oil) in the food industry as a source of functional food in drinks, beverages and ice creams. Lemongrass extract, polymers of carbohydrate and inorganic components could also be used as a preservative coating material for fruits. Due to its ability to form a semi-permeable film, lemongrass extract coating might be expected to modify the internal atmosphere of fruit and decrease transpiration losses. In a study, it is reported that lemongrass extract coating had the potential to prolong storage life and control decay of table grape (Castillo *et al*., 2010). Different inorganic salts were used to protect the harvested fruits from fungal pathogens, such as potassium metabisulphite, potassium bicarbonate, sodium bicarbonate, calcium chloride, ammonium molybdate and sodium carbonate (Sharma *et al*., 2009). Among them, sodium bicarbonate (SBC) which is regarded as safe salts with fungistasis property can be used to control postharvest diseases. SBC is able to reduce severity of anthracnose on mango (Hasan *et al*., 2012), apple scab (Ilhan *et al*., 2006) and blue molds of clementine mandarins (Palou *et al*., 2002). It also enhanced the activity of biocontrol agents such as *Trichosporon pullulans* (Yao *et al*., 2004), *Bacillus subtilis* (Obagwu and Korsten, 2003) and *Pseudomonas syringae* (Plaza *et al*., 2001).

The quality of mango fruits is largely dependent on the varieties and various postharvest treatments which are principally applied to increase the storability of fruits. It is essential to understand the physico-chemical changes of mango to improve the postharvest quality of the fruits. A large number of research works on shelf life and quality as influenced by different postharvest treatments has been extensively investigated by a number of scientists in different parts of the world. Although considerable literature dealing with shelf life extension, postharvest loss reduction and physico-chemical changes during storage and ripening of mango is available, but as far we know that there is no work using antagonistic bacterial coating on fruits to extend shelf life have been done in Bangladesh, especially with mango fruits. Thus, this study was conducted to study the biocontrol performance of selected antagonistic bacteria *Stenotrophomonas rhizophila* strain PSTU-Hort-14 with 2% SBC and 20% lemon grass extract on the shelf life and postharvest quality of BARI Aam-3 fruits under refrigerated conditions.

Materials and Methods

Mango fruits of ‘BARI Aam-3’ variety at color stage two (green with tinge of yellow) were used for postharvest treatments. Healthy fruits with uniform size, shape, and maturity were collected from Regional Horticultural Research Station (RHRS), BARI, Lebukhali, Patuakhali. Three treatments were selected as factor A for this study, which were i) combined treatment of SBC, lemongrass extract, bacterial strain PSTU-Hort-14 (cell suspension of bacterial strain PSTU-Hort-14 (10^8 CFU mL^{-1}) in

combination with 20% lemongrass extract and 2% SBC solution); ii) positive control (Dipheniconazol® solution at the rate of 0.50 mlL^{-1}) and iii) negative control (sterilized distilled water). Whereas storage durations act as factor B. Forty four fruits were dipped in each treatment and the total number of fruits were 132. Every week, eight fruits represented five replications (two fruits per replicate) for each treatment were used for determination of physico-chemical characteristics. Data were recorded on 0, 7, 14, 21, and 28 days of storage (12±1ºC and 90±5% RH).

Determination of physical characteristics

Weight loss

To determine the fruits weight loss, fruits weight were measured every alternative day by weighing individual fruit with a top pan electronic balance (Model-668ALED, RFL).

Determination of pulp firmness (N)

Firmness of mango were determined by firmness testing machine (Model: GY 4). This method was mentioned by Hassan (2006).

The pulp to peel ratio was measured with the following formula-

$$Pulp\ to\ peel\ ratio = \frac{Weight\ of\ fruit\ pulp}{Weight\ of\ peel}$$

Determination of glossiness

Glossiness of mango was determined by gloss meter (Model: ETB-0686). Gloss is measured by directing a constant intensity light beam, at a fixed angle, on to the test surface and then monitoring the amount of reflected light from the same angle. This specular reflectance was measured using a gloss meter. A gloss meter provides quantifiable gloss measurements, expressed as gloss units (GU).

Determination of chemical characteristics

Determination of titratable acidity

Titratable acidity (TA) was determined according to the method by Ranganna (1977).

Determination of pH

The remaining of the filtrated juice from TA determination was used to measure the pH of the fruit pulp. The pH was determined by using a glass electrode pH meter (PHS-25 Precision pH/mV meter, LIDA Instrument).

Determination of soluble solids concentration

The soluble solids concentrations of fruits pulp were determined by using a digital refractometer (BOE 32195, BOECO, Germany).

Determination of ascorbic acid

Ascorbic acid was determined according to the dye method by Ranganna (1977).

Determination of total sugar

Sugar content of fruit was estimated by the following procedures described by the Lane and Eynon (1923).

Standardization of fehling's solution

Fifty ml of both fehling's solution A and fehling's solution B was mixed together in a beaker. Ten milliliter of mixed solution was pipette into a 250 ml conical flask and 25 ml distilled water was added to it. Standard sugar solution was taken in a burette. The conical flask containing mixed solution was heated on a hot plate. When the solution began to boil, three drops of methylene blue indicator solution was added to it without removing the flask from the hot plate. Mixed solution was titrated by standard sugar solution. The end point was indicated by decolorization of the indicator. Fehling's factor was calculated by using the following formula:

$$Fehling's\ factor\ (g\ of\ invehrt\ sugar) = \frac{Titre \times 2.5}{1000}$$

Preparation of sample

50 ml fruit juice was mixed with 100 ml of distilled water and 5ml of neutral led acetate solution and then kept for ten minutes and the mixture was homogenized. Then the blended material was transferred to a 250 ml volumetric flask. The volume was made up to the mark with distilled water. The solution was then filtered.

Determination of reducing sugar

Ten ml of mixed fehling's solution was taken in a 250 ml conical flask and made 250 ml with distilled water. Purified juice solution (filtrated) was taken in a burette. Conical flask containing mixed fehling's solution was heated on a hot plate. Three to five drops of methylene blue indicator were added tom the flask when boiling started and titrated with solution taken in burette. The end point was indicated by decolorization of indicator. Percent reducing sugar was calculated according to the following formula:

$$Reducing\ sugar\ (\%) = \frac{F \times D \times 100}{T \times W \times 1000}$$

Where,

F: Fehling's solution

D: Dilution

T: Titre, and

W: Weight of sample

Determination of total invert sugar

Fifty ml of purified solution (filtrated) was taken in a 250 ml conical flask. Five ml citric acid and 50 ml distilled water was added to it. The conical flask containing sugar solution boiled for inversion of sucrose and cooled: Then the solution was transferred to a 250 ml volumetric flask and neutralized by 1N NaOH using phenolphthalein indicator. The volume was made up to the mark with distilled water. Then the mixed fehling's solution was titrated using similar procedure followed as incase of invert sugar (reducing sugar) mentioned earlier. The percentage of total invert sugar was calculated by using the formula used in incase of reducing sugar.

Estimation of non-reducing sugar

Non-reducing sugar was estimated by using the following formula:

Non-reducing sugar (%) = Total invert sugar (%) - Reducing sugar (%)

Sensory evaluation of ripe fruit

Sensory analyses to compare the quality of treated and control mango fruits were carried out by eight trained adults, aged 25-40 years (four male and four female). The panel were trained in a pre-test in which mango fruits with extremely low or high attributes (taste, peel color, pulp color, texture and flavor) were evaluated. Evaluations were based on the Table 3 hedonic scale. After the sensory evaluation, the overall rating of the sensory trail was taken according to Ali *et al*. (2011) with some modifications. The panelists were asked to score the differences between the samples by allotting the numbers from 0 to 5 against Excellent (5), Very good (4), Good (3), Fair (2), Poor (1), and Very poor (0).

Experimental design and statistical analysis

The factorial treatments were laid out in a completely randomized design with five replications. The recorded data on different parameters of the experiment were tabulated and analyzed with appropriate design of experiment (Gomez and Gomez, 1984) adopting a statistical programme MSTAT-C. All the treatment means were calculated and the analyses of variances (ANOVA) of different parameters considered were done by 'F' variance test. The means were separated by Least Significant Difference (LSD) test at 5% level of significance.

Results

Changes in physical characteristics

Weight loss

Mango fruits under all the treatments showed a progressive loss of weight during four weeks of storage at 14 ºC and 95% RH (Fig. 1). However, significantly ($P \leq 0.05$) lower weight loss was recorded with the combination of SBC-Lemongrass extract-*Stenotrophomonas rhizophila* dipped mango compared to negative control and positive control treated fruits. The values ranged between 0.9 to 3% for the combined treatment

after 7 to 28 days of storage. The negative control and positive control treated fruits, on the other hand, exhibited maximum weight loss at each storage interval with the values 5.53% and 3.62%, respectively after the end of storage. 12 ºC and 95% RH for 28 days. Each value is the mean of four replications. Means were separated by Least Significant Difference (LSD) test at 5% level of significance. Vertical bars represent standard error

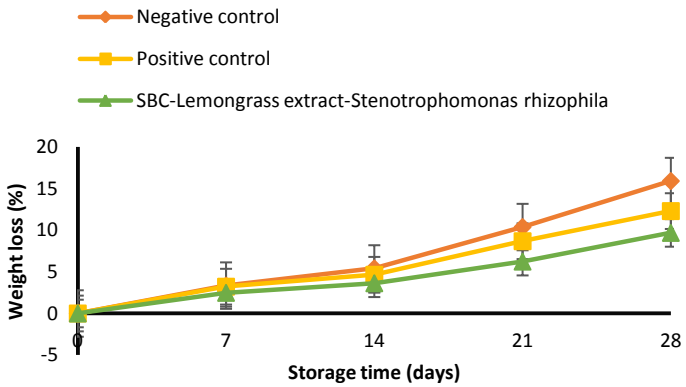

Fig. 1. Effects of different treatments on the weight loss of mango fruits during storage

Flesh firmness

The initial firmness of mango flesh was noted maximum (58.31 N) and the values were noticed similar for control and treated samples. The firmness gradually declined for all fruits with the period of storage advanced; however, the decrease was significantly slower in the combined treatment SBC-Lemongrass extract-*Stenotrophomonas rhizophila* (Fig. 2). The flesh firmness under the combined treatment was consistently higher than those of negative control and positive control treated fruits during entire storage period.

Mango fruits that were subjected to the combination of SBC-Lemongrass extract-*Stenotrophomonas rhizophila* maintained the firmness of 25.70 N after 28 days of storage, which were the readings for the negative control and positive control treated fruits on day 12 or 13 of storage. Hence there was a gain of at least 15 days of extra storage life with the application of this combined treatment.

Glossiness of fruit

Glossiness of mango fruit was measured by a gloss meter during the storage of 28 days at 14 ºC. A gloss meter provides quantifiable gloss measurements, expressed as gloss units (GU). However, the glossiness can be slowed down by the combined treatment of SBC-Lemongrass extract- *Stenotrophomonas rhizophila*.

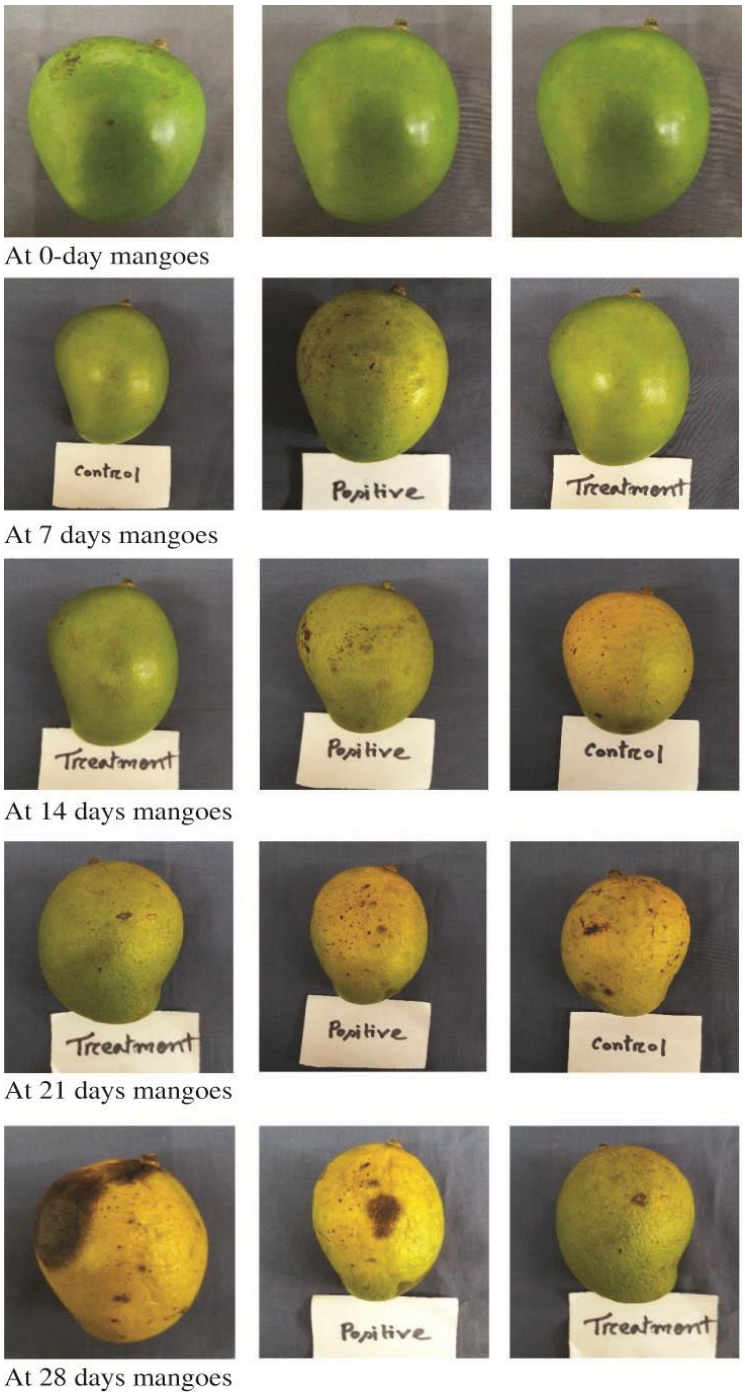

Fig. 2. Effects of combined treatments of SBC-Lemongrass extract-*Stenotrophomonas rhizophila*, positive control (Dipheniconazol®) and negative control (sterilized distilled water) on the physical appearance of mango fruits during storage at 12±1ºC and 90±5% RH for 0, 7, 14, 21 and 28 days

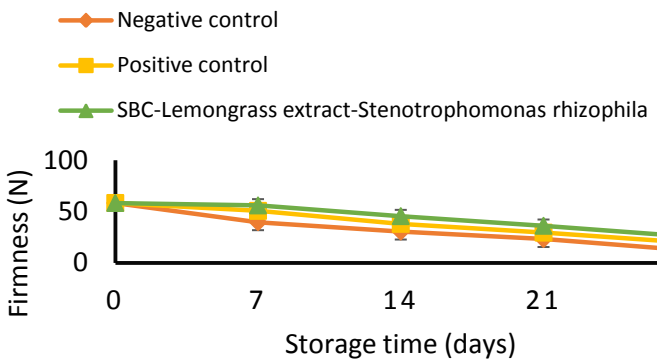

Fig. 3. Effects of different treatments on the flesh firmness of mango fruits during storage at 12ºC and 95% RH for 28 days

Changes in chemical characteristics

Titratable acidity (%)

Titratable acidity of mango fruits gradually decreased with advancement of time during storage (Fig. 4). Significantly the highest TA (1.78%) was recorded in fruits at the beginning of storage (0 days), which declined slowly with storage time and reached at minimum level (0.63%) at the end of storage period. However, fruits that were subjected to the combination of SBC-Lemongrass extract-*Stenotrophomonas rhizophila* exhibited slower decline for the concentration of TA. At the end of storage, the lowest (0.63%) TA was recorded in combined treatment of SBC-Lemongrass extract-*Stenotrophomonas rhizophila* and the highest TA was recorded in negative control (0.94%).

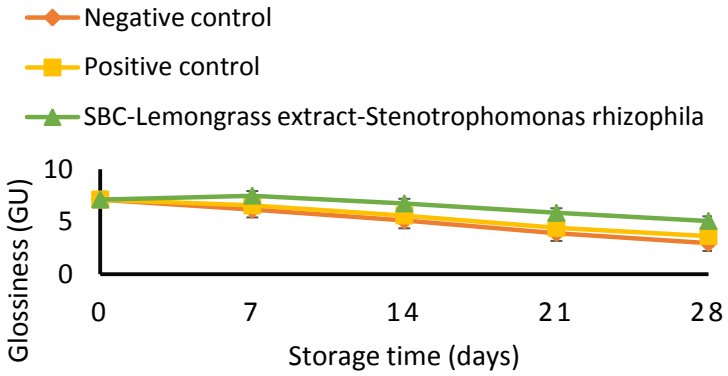

Fig. 4. Effects of different treatments on the glossiness of mango fruits during storage at 12ºC and 95% RH for 28 days

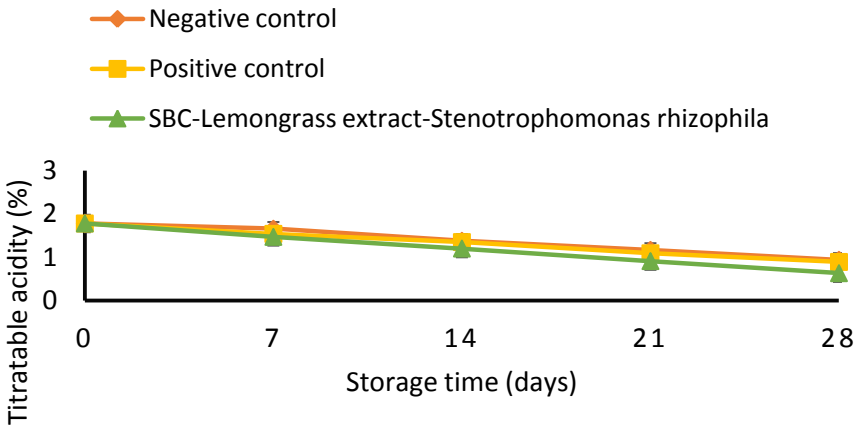

Fig. 5. Effects of different treatments on the titratable acidity of mango fruits during storage at 12ºC and 95% RH for 28 days

pH

The pH of fruit increased gradually as storage progressed with yielding significant differences ($P \leq 0.05$) between the treatments. At the end of storage period of 28 days, pH value was manifested significantly higher (4.86) in fruits subjected to the combination of SBC-Lemongrass extract-*Stenotrophomonas rhizophila* compared to that of water treated control fruits with the value of 4.21.

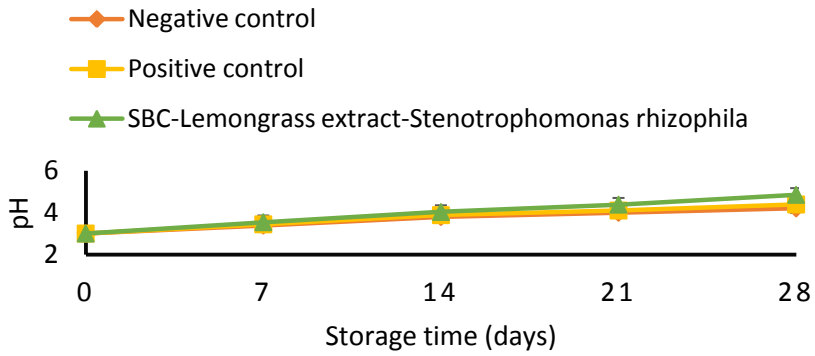

Fig. 6. Effects of different treatments on the pH of mango fruits during storage at 12ºC and 95% RH for 28 days

Soluble solids concentration (SSC)

The SSC of negative control and positive control treated fruits were fairly low initially (1.51) and increased gradually with the advancement in storage period and reached maximum values of 4.06 and 4.22%, respectively after 21 days of storage. After this period, noticeable decrease in SSC was recorded. The sharp decline in SSC values indicated faster metabolic rates of the negative control and positive control treated fruits.

On the other hand, the fruits that were treated with the combination of SBC-Lemongrass extract-*Stenotrophomonas rhizophila* showed gradual changes and reached maximum SSC (4.83%) at the end of 28 days of storage period.

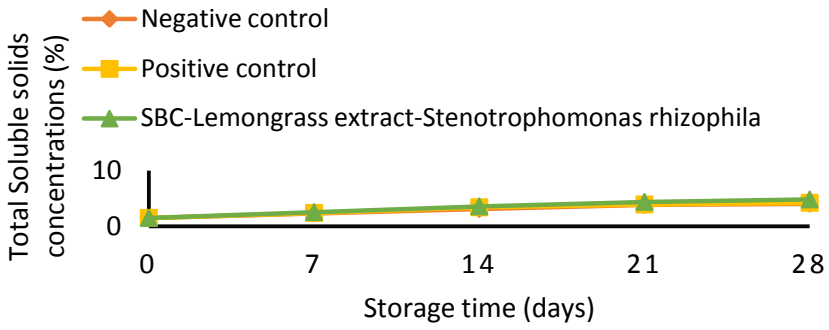

Fig. 7. Effects of different treatments on the TSS of mango fruits during storage at 12ºC and 95% RH for 28 days

Ascorbic acid content

It is evident that the combination of SBC-Lemongrass extract-*Stenotrophomonas rhizophila* induced significant variation in ascorbic acid content of mango fruit during storage. Initially the ascorbic acid content was 10.14 mg 100 g^{-1}. In negative control fruit, the content of ascorbic acid decreased sharply over time and reached minimum value of 6.04 mg 100 g^{-1} after 14 days of storage and thereafter declined until end of 28 days of storage. Almost similar trend was observed for positive control treated fruits. However, fruits that were subjected to the combined treatment SBC-Lemongrass extract-*Stenotrophomonas rhizophila* showed more gradual changes in ascorbic acid content with time and exhibited minimum value of 5.10 mg 100 g^{-1} after 21 days of storage and declined gradually thereafter. After the end of 28 days of storage, there were no statistical

Reducing sugar

In all fruits the reducing sugar values increased with the storage period. However, slower increase was observed with the combined treatment indicating delayed ripening. For all treatments the values of reducing sugar (3.48%) were recorded the same in fruits at the beginning of storage (0 days). At the end of storage, the highest (5.33%) reducing sugar was recorded in the combined treatment of SBC-Lemongrass extract-*Stenotrophomonas rhizophila* and the lowest reducing sugar was recorded in the treatment negative control (4.48%).

Differences regarding ascorbic acid content amongst the treatments.

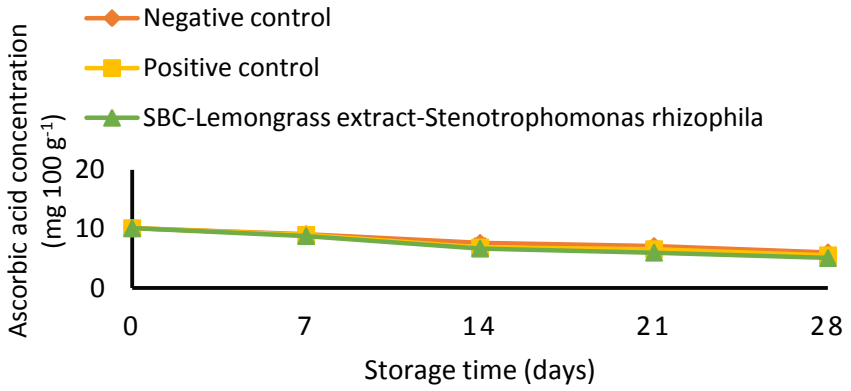

Fig. 8. Effects of different treatments on the ascorbic acid concentration of mango fruits during storage at 12ºC and 95% RH for 28 days

Non reducing sugar

Non reducing sugar values decreased with the storage period. However, slower decrease was observed with the combined treatment indicating delayed ripening. For all the treatments the highest non reducing (3.43%) was recorded in fruits at the beginning of storage (0 days). At the end of storage, the lowest (0.34%) non reducing sugar was recorded in the combined treatment of SBC-Lemongrass extract-*Stenotrophomonas rhizophila* and the highest non reducing sugar was recorded in negative control (0.94%).

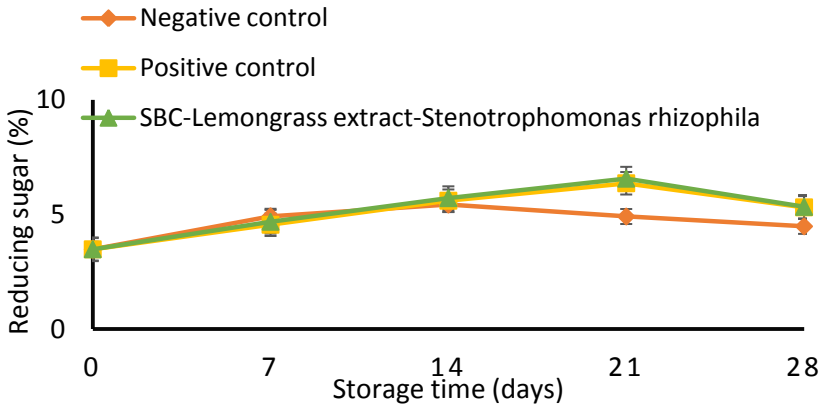

Fig. 9. Effects of different treatments on the reducing sugar of mango fruits during storage at 12ºC and 95% RH for 28 days

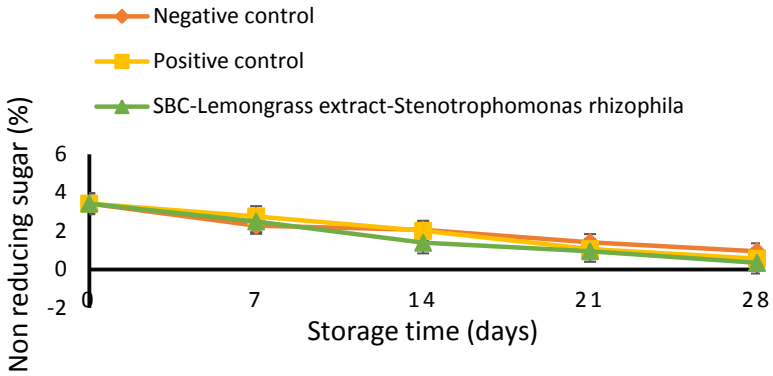

Fig. 10. Effects of different treatments on the reducing sugar of mango fruits during storage at 12ºC and 95% RH for 28 days

Total sugar

The total sugar values decreased with the storage period in all fruits. However, slower decreasing trend was observed with the combined treatment indicating delayed ripening. For all the treatments the total sugar content of mango fruits decreased rapidly during the storage period with significant negative linear relationships. The highest total sugar (6.91%) content was recorded in fruits at the beginning of storage (0 days) for all the treatments. At the end of storage, the highest (5.87%) total sugar was recorded in the combined treatment of SBC-Lemongrass extract-*Stenotrophomonas rhizophila* and the lowest content was recorded in negative control (5.43%).

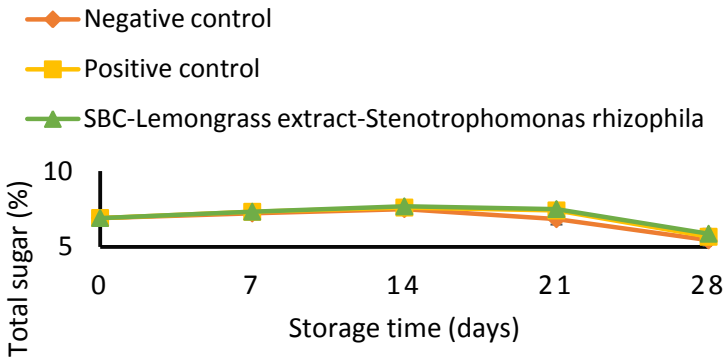

Fig. 11. Effects of different treatments on the total sugar of mango fruits during storage at 12ºC and 95% RH for 28 days

Sensory analysis

Panelists evaluated the visual aspect of the fruits and gave the lowest scores to those of negative control fruits, which ripened after 3 weeks of storage. The fruits began

to decompose after three weeks. The fruits treated with SBC-lemongrass extract-*Stenotrophomonas rhizophila* attained maximum scores by the panelists for all the parameters evaluated. The fruits were glossy and wrinkless, therefore scored 3.85, which was significantly ($P \leq 0.05$) higher than positive control treated fruits. The positive control treated fruits also had a good overall appearance but with some wrinkles. The most attractive pulp with the characteristic of golden yellow color of mango was found in fruits treated with SBC-lemongrass extract- *Stenotrophomonas rhizophila* (3.95), followed by positive control (3.31) treated fruits.

Table 1. Effect of combined treatment SBC-Lemongrass extract-*Stenotrophomonas rhizophila*, positive control (Dipheniconazol®) and negative control (distilled water) on the sensory traits of mango fruits after four weeks of storage at 12±1°C

Treatments	Taste	Peel color	Pulp color	Texture	Flavor
Negative control	0.00 c	0.00 c	0.00 c	0.00 c	0.00 c
SBC- lemongrass extract-*Stenotrophomonas rhizophila*	4.17 a	3.78 a	3.95 a	3.85 a	4.50 a
Positive control	3.50 b	2.90 b	3.31 b	3.65 b	3.90 b

Means in each column followed by the same letter (s) are not significantly different at $P \leq 0.05$ according to Least Significant Difference test

There were significant ($P \leq 0.05$) differences in the texture of the fruits with the different treatments. Fruits with combined treatment were rated the highest (4.17 points), with a firm, crispy pulp and 'melted' in mouth. The flavor was also rated excellent (4.50) because the pulp was not only sweet and pleasant, but also possessed the characteristic aroma.

Discussion

The mechanism for these positive effects is based on the interplay of the biocontrol activity of SBC-*Stenotrophomonas rhizophila* and moisture barrier properties of lemongrass extract and *Stenotrophomonas rhizophila*. In this combination, lemongrass extract acted as a carrier of *Stenotrophomonas rhizophila* and SBC as well as coating, at the same time *Stenotrophomonas rhizophila* produces biofilm which was mentioned by Morikawa (2006) in his review article. The combination of biofilm of *Stenotrophomonas rhizophila* and lemongrass extract coating modified the micro atmospheric environment surrounding the fruits with reduced O_2.

Transpiration is a mass-transfer process in which water vapor moves from the surface of fruits or vegetables to the surrounding air. This process of moisture loss induces wilting, shrinkage, and loss of firmness and crispiness of fruits and vegetables and thus, adversely affects the appearance, texture, flavor and mass of produce (DeEll *et al.*, 2003). Paull and Chen (1989) reported that mango fruits weight loss greater than 8% considerably diminished the postharvest quality. However, weight loss in SBC-lemongrass extract-*Stenotrophomonas rhizophila* treated fruits were significantly reduced

when stored at 12±1ºC for 28 days, which is considered to be acceptable for retailing purposes. This reduction of weight loss coincided with the reduction in respiration rate. As with other edible coatings, lemongrass extract prevented moisture loss and controlled respiratory exchange. In general, this positive effect of edible coatings is based on their hygroscopic properties, which enables formation of a water barrier between the fruit and environment, and thus avoiding its external transference (Morillon *et al.*, 2002). To enhance water barrier efficacy, many formulations of composite coatings are utilized, the most frequently used being polysaccharide-lipid. Thus, increasing lipid content of coating formulations significantly reduced weight loss of mandarins (Pe´rez-Gago *et al.,* 2002). However, for lemongrass extract which the composition is mainly polysaccharides (Ni *et al.,* 2004), was highly effective as a moisture barrier without lipid incorporation. In this study, *Stenotrophomonas rhizophila* and 2% SBC were used with lemongrass extract to make a composite coating with antifungal and moisture barrier properties. Here, *Stenotrophomonas rhizophila* used were for dual purposes. Firstly, to control disease specially postharvest anthracnose disease and secondly, to make a biofilm, which increase the efficiency of lemongrass extract coating. In this formulated coating, SBC used to control anthracnose and increase the concentration of composite coating. Thus, resulting in decreased diffusivity of water vapor through the composite coating and a decreased in hydrophilic tendency of lemongrass extract and increased antifungal properties.

In general, surface coatings have been applied to many fruits and vegetables to maintain or enhance gloss and improve storage quality. Dang *et al.*, (2008) also reported that the external colour of mango fruit is generally retained when coated with lemongrass extract. Similarly, in this study, the extent of skin color development of mango fruit was significantly slower when treated with the combination of SBC-lemongrass extract-*Stenotrophomonas rhizophila* compared to negative control or positive control treated fruits. This combined treatment showed the best control of skin color change throughout the storage, suggesting a delay in the ripening of the fruits. The delay in skin color development of mango exposed to the combination of SBC- lemongrass extract - *Stenotrophomonas rhizophila* in this investigation could also be related to its effect on in modification of internal atmosphere of the fruits. These conditions delayed ripening and senescence process, thus resulting in retention of greenish yellow color and firmness of fruits.

The combination of SBC- lemongrass extract -*Stenotrophomonas rhizophila* slowed down the increase in concentration of total soluble solids and reduced the decrease in content of titratable acidity of mango during storage. These might be due to the semi-permeable coating formed by the combination of lemongrass extract - *Stenotrophomonas rhizophila* around the fruit surfaces, which was very effective in reducing disease incidence and severity, delayed the ripening process and consequently all other activities associated with ripening were also suppressed. Lower respiration rate and ethylene production of the mango fruits treated with the treatment were observed during storage at 12°C for 28 days. Thus, the slower increase in SSC and higher level of titratable acidity in the pulp of mango fruits that were subjected to the treatment could probably due to reduction of oxygen supply on the fruit surface, which inhibited

respiration rate and the growth of spoilage organisms (Yonemoto *et al.*, 2002). The incorporation of 2% SBC in the combined treatment in this work presumably reduced the rate of ripening and eventually the gradual changes in soluble solids concentration and sugars seem to be under the direct control of interaction with the disease of mango (Hasan *et al*., 2012). Results of this study are in agreement with the findings of previous works on various fruits coated with lemongrass extract-based coatings, such as Sweet cherry mango (Dang *et al.,* 2008). Decrease in acidity during storage and ripening most probably due to utilization of organic acids in the respiration resulting increase in pH of the fruits. In another study, Ghanta *et al.* (1994) also reported that the titratable acidity in mango fruit decreases gradually throughout the fruit development until it reaches the full ripe stage. In this study, the increased in pH and decrease in titratable acidity of mango followed a linear trend with increased in storage period for both coated and uncoated fruits. However, the combined treatment in the current work slowed the changes of pH and titratable acidity during storage which effectively delayed fruit senescence. Slowing down the respiration rate in fruits by means of this treatment could explain the delay in the use of organic acids in the enzymatic reactions of respiration, thus retarding ripening (Hernandez-Munoz *et al.,* 2006).

The trend of development of ascorbic acid in mango fruit increased during ripening but, declined by the end of storage. However, postharvest application of SBC-lemongrass extract *Stenotrophomonas rhizophila* exhibited a best effect on the content of ascorbic acid by slowing down its increasing rate and no any decreasing trend like negative and positive controls treated fruits with storage time, which can be attributed to low respiration rate (Jiang *et al.,* 2001). The content of ascorbic acid in fruits that were subjected to the treatment increased steadily until 21 days of storage and then decreased slightly till the end of storage. This slower increase in ascorbic acid content might be due to reduced internal oxygen that resulted in retarding the oxidation of ascorbic acid.

Moreover, the lemongrass extract coating imparted an attractive natural-looking sheen to the mango fruit, almost liked a freshly harvested fruit with lower changes in both skin color and dehydration. The visual aspect of the fruit is usually correlated to the overall quality, where firmness, crunchiness, juiciness and sweetness of fruit were significantly higher in SBC- lemongrass extract -*Stenotrophomonas rhizophila* treated fruit compared with the negative control or positive control treated fruits. It is interesting to point out that none of the panelists could discern any bad odor or "off-flavor" attributed to the SBC- lemongrass extract -*Stenotrophomonas rhizophila* treatment.

Conclusion

Utilization of biocontrol agents as the postharvest treatment in managing disease of tropical fruits is more acceptable for marketing in the developed countries where their phytosanitary regulations is stringent because they are moving toward reducing use of synthetic fungicides. It was found that lemongrass extract and SBC not only enhanced the biocontrol efficacy of *stenotrophomonas rhizophila* strain PSTU-Hort-14, but also manage to improve the storability of mango by reducing moisture loss without compromising the fruit quality. Fruits treated with the combination of SBC- lemongrass extract -*Stenotrophomonas rhizophila* reduced transpiration rate stored at 12±1^{o}C and

90±5% RH. This suggest that the treatment significantly retained fruit firmness, decreased weight loss and delayed the changes in external color, soluble solids concentration and ascorbic acid contents of the fruit during storage. It also suggests that this composite coating is promising as a natural, harmless and eco-friendly coating to be used in commercial postharvest applications for prolonging the shelf life of mango.

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Conflicts of interest

The authors declare no conflicts of interest regarding publication of this paper.

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