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Effect of Hot Water Treatments on Postharvest Life of Seeni Kesel Banana (*Musa* spp.cv. Seeni Kesel-Pisang Awak, ABB)

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Authors' contributions

This work was carried out in collaboration between all authors. Author PKD designed the study, wrote the protocol, and wrote the first draft of the manuscript. Authors PKD, MLMCD and WMAUMW managed the literature searches, analyses of the study and discuss the conclusion. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To evaluate the effect of hot water treatments on shelf life and de-greening of stored Seeni Kesel banana (*Musa* spp. cv. Seeni Kesel-Pisang Awak, ABB), which is commonly grown in Sri Lanka.
Study Design: A randomized complete block design with six replicates was used.
Place and Duration of Study: The experiment was conducted in Faculty of Agriculture, Sabaragamuwa University of Sri Lanka, Sri Lanka during April to July experimental period in 2012.
Methodology: Banana fingers were dipped in hot water regimes of 30°C, 40ºC, 50°C and 60°C for 5 and 10 min in experiment 1 and 35ºC, 40ºC, 45ºC, 50ºC and 55ºC for 5 min in experiment 2 using a hot water bath. Fruit surface colour was evaluated by a scoring method, total soluble solid content of fruits, taste level, and *in vitro* microbial growth were recorded. Five fingers were included in a replicate.

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Results: Banana fingers treated with 40ºC remained green with 6.25 scores whereas control reduced it significantly to 4.75 on day 3 of storage. However, both 30ºC and 50ºC treated fruits were in same value and no significant difference in colour scores than 40ºC. There were no significant differences of scores for taste and Brix value among different hot water treatments compared to the control. Over 40ºC hot water treatment suppressed *in vitro* microbial growth significantly from 0.1cm to 0 compared to control (0.8 cm).
Conclusion: These analyses showed that 40ºC was comparatively best hot water treatment to reduce the de-greening of 'Seeni Kesel' banana and hence increase the postharvest life without affecting consumer preference. Hot water treatments over 40ºC significantly suppressed the *in vitro* growth of microbes on fruit surface.

Keywords: Banana; postharvest life; de-greening; microbial control.

1. INTRODUCTION

Banana (*Musa* spp.) is one of the dominant fruits produced in the world after citrus and grapes [1] with volume of global gross exports of 16.5 million tonnes in 2012 which was 7.3% more than 2011 level [2]. However, high perishable nature of banana always makes traders unhappy due to quality deterioration which distracts consumer and hence high postharvest losses in the market. The banana losses in the market are more significant especially in less developed countries. Climacteric nature of banana make these postharvest losses accelerate by triggering ethylene induced ripening process [3]. Extending banana shelf life could be a considerable commercial benefit for both exporters and retailers.

Many storage techniques have been developed to extend the shelf life and prolong freshness of banana for exporting purposes. Cold storage of 13ºC is practiced by developed nations to slow down fruit metabolism and therefore prolong senescence [4]. However, this is costly, and rapid fruit re-warm on the display shelves tend to reduce shelf life [5]. Most research has focused on ways to extend the green life of unripe fruit. Modified atmosphere packaging and ethylene absorbent packaging have been suggested as substitutes for low temperature storage [6], however, these storages are costly as it involves more labour for careful handling to prevent damage to bags and to keep the modified atmosphere conditions.

1-methylcyclopropene (1-MCP) treatment effectively delay peel colour change and fruit softening, and extend shelf life in association with suppression of respiration and C_2H_4 evolution [7]. Ethylene scrubbing, considered beneficial in storage of climacteric fruits and vegetables [8], may therefore be unnecessary with heated fruit. Use of ethylene oxide and sulphur dioxide is also effective in extending shelf life in Giant Cavendish banana [9].

Heat treatment is one of these postharvest techniques which have been used as a plant quarantine procedure in mango, apple, avocado, and litchi [10]. Indeed, the overall quality of fresh produce treated with optimal hot water temperatures is significantly better than untreated produce, as determined by a sharp reduction in decay incidence and maintenance of several quality traits [11,12]. Exposing fruit to high temperatures attenuates some of these processes reduce while enhancing others. This anomalous situation results in heated fruit being more advanced in some ripening characteristics than non heated fruit while maintaining their quality longer during shelf life at 20ºC [13].

Postharvest diseases also could be suppressed by postharvest heat treatments as evidenced by many experiments which have been conducted on many fruit crops [14,15]. There is a growing demand to decrease the postharvest use of chemicals against pathogens and insects. Heat treatment substitutes as a non-damaging physical treatment for chemical prevention [16]. Most postharvest diseases are controlled by fungicides immediately after harvest as a spray or dip application. They are becoming increasingly unpopular as a result of increasing awareness among consumers about fungicide residues. So there is a need to develop effective, non damaging physical treatments disease control in fresh horticultural products.

Though, Many works of hot water treatments on banana (different cultivars) were done with the purpose of controlling disease incidence [10,11,12] this study is mainly focusing on effect of hot water treatments as a physical treatment for reducing de-greening and hence the postharvest life of locally available seeni kesel

banana (*Musa* spp. cv. seeni kesel-pisang, ABB) in Sri Lanka.

2. MATERIALS AND METHODS

2.1 Plant Material

'Seeni Kesel' banana cultivar which are in same growth stages were harvested from farmers field in Belihuloya, Sri Lanka and transported to the laboratory after packing in cardboard boxes. Upon arrival at the laboratory, 'seeni kesel' banana hands were immediately sorted and evaluated for initial skin colour. Free of visual defects and of uniform coloured, size and shape hands were selected and cleaned. A sharp knife was used to de-hand the banana. Five fruits were used for one treatment and replicated Six times.

2.2 Hot Water Treatments

Fruit hands were separated into two sets and one set dipped in water for 5 minutes at 30°C, 40°C, 50°C and 60°C and other set for 10 minutes in same temperature regime in experiment 1. Water in room temperature (25ºC) was used as the control treatment. In Experiment 2 closer temperature intervals (5ºC intervals) of hot water treatments were used than that of the experiment 1 (10ºC intervals), especially with objective to find out precise hot water temperature. Fruits hands were dipped in water at temperature regime 35°C, 40°C, 45°C, 50°C and 55°C for 5 minutes. Ten liter (10 L) double distilled water was used in hot water bath to make different hot water temperature regimes. Water was heated until desired temperature and kept the banana to be treated in the water at assigned duration. Treated banana was blotted using blotting papers to remove water and stored in perforated (with two holes of 4 mm diameter each) 4 µm polyethylene bags. The bags containing treated fruits were placed in 30 x 30 x 60 cm cardboard boxes in dark. Average room temperature during the experiment was 25°C±2 and relative humidity was 70%±2.

2.3 Physical and Chemical Analyses

Quality changes, of fruits after treatments were tested such as surface colour, total soluble sugar content of fruits, taste level. Surface colour changes of fruit peel were assessed for ripening using a colour scores such as, 1= green, 2=colour break, 3=more green than yellow, 4=more yellow than green, 5=yellow with green tip, 6=full yellow, and 7=over ripe [17]. Sugar content was detected as Total Soluble Solid by degrees of brix value. Banana finger separately homogenized and squeezed and filtered in a muslin cloth and few drops of filtered juice was placed on the refractometer (ATAGO, Japan) and read the brix value. For test the taste level, 10 persons ranged from 25 years to 35 years old were randomly selected and asked to taste the banana and to score the taste level of ripen fruit from 1 to 5. Scores were 1,2,3,4 and 5. Score 1 was marked when fruits not palatable, score 5 for acceptable taste and 2,3,4 were marked in between not palatable and acceptable taste accordingly.

2.4 Microbial Enumeration

Growth of microorganisms from hot water treated fruits was investigated. Parts of banana peels (1-2 mm size) were cut-off from randomly selected hot water treated banana (35°C, 40°C, 45°C, 50°C and 55°C for 5 minutes and 10 minutes) and placed on potato dextrose agar medium to observe the *in vitro* growth of microorganisms. The *in vitro* growth of microorganisms from cultured banana peel was recorded using a scaled ruler (cm) by measuring diameter of the colony every day until day 6. Types of microorganism were identified based on morphological features. One liter of potato dextrose agar was prepared using 4g potato effluent from 200g boiled potato, 20g of Dextrose and 20g of Agar. pH of the medium was 5.6± 0.2 at 25ºC.

2.5 Data Analysis Experimental Design and Statistical Analyses

Each point of score data was analyzed using Kruskal-Wallis Test at 0.05 probability level. Mood median test was done to find the difference between individual treatments. Each point of Non scoring data were analyzed by ANOVA and mean separation was done by Duncan's Multiple Range Test. Standard error was calculated while marking error bars in Fig. R software was used for statistical analysis [18].

3. RESULTS AND DISCUSSION

3.1 Colour

On average, degree of green colour in all bananas treated with different hot water treatments dramatically reduced in different rates during 6 days of storage (Fig.1-A). There were no significant colour changes in banana fingers among different heat treatments until two days of storage. On day 3 of storage there was a

significant difference of colour scores between control and 40ºC heat treatment. Banana fingers treated with 40ºC remained green with 6.25 scores whereas control reduced it significantly to 4.75 on day 3 of storage. However, both 30ºC and 50ºC treated fruits were in same value (5.75) and no significant different in colour scores than 40ºC. Further, on day 4 colour scores of banana treated with 30ºC was similar to the control and significantly lower than 40ºC. On day 6 the colour scores between 40ºC and control were more apart compared to the other days. Banana treated with 30ºC was also made significant difference in colour scores compared to 50ºC (Fig.1-A). The scores for 60ºC is not showed in the Fig. as all bananas blackened immediately after heat treatments and made it unsuitable for consumption.

Fig. 1-B shows the colour scores for banana as a result of hot water treatments of 30ºC, 40ºC, 50ºC, and 60ºC for 10 minutes. More or less the results were sort of duplication of the above (Fig. 1-A). Result of treatment 60ºC is not presented in Fig. 1-B, as the banana fingers turned black immediately after the treatment. Though the banana treated with 50ºC for 10 minutes showed blackening in few points on the skin, results are used in the Fig. as the blackening was slight and not made damages to the surface appearance. On day 3 onward colour scores for treatments 30ºC and control significantly reduced compared to both 40ºC and 50ºC. However, 50ºC showed significantly low colour scores (more yellowing) than 40ºC and tend to reduce the difference between colour score of control.

Based on the experiment 1, the second experiment was conducted with hot water treatments of 35ºC, 40ºC, 45ºC, 50ºC and 55ºC for 5 minutes. As banana fingers were blackened by the 55ºC, colour scores for 55ºC were not given. All treatments, after two days of storage, showed significantly high colour scores than control except 45ºC and 50ºC on day 3 (Fig. 2).

These results proved that there were relationship between hot water treatment and de-greening in seeni kesel banana. The de-greening recorded by colour scores directly related to the ripening of banana. The inhibition of ripening by heat may be mediated by its effect on the ripening hormone ethylene [13]. Heat treatment inhibited ethylene synthesis in both apples and tomatoes within a few hours [19,20]. Apples held at 20ºC after a heat treatment showed a lag in ethylene production compared with non heated fruit. Further, inactivation of chlorophyll degrading enzymes activity as a result of hot water treatment is also a possible reason for reducing the de-greening [21]. However, these results indicated that there is a limit for application of heat treatment as 50ºC which showed high yellowing than 40ºC.

Hot water treatments 55ºC and 60ºC were not suitable for seeni kesesl banana as all banana peels were immediately blackened, an attribute to distract the consumer. Despite the fact that high temperature reduced de-greening in seeni kesel banana, over 45ºC of hot water treatment lowered the scores during storage and hence more ripening compared to 40ºC. Suppressed ethylene Production eventually recovered, even exceeded control levels [20,22]. This might be the reason for rapid de-greening of seeni kesel at 50ºC treatment for 10 minutes after day 5 storage (Fig. 1-B). However, some scientists [23] have suggested that hot water treatment at 50ºC for 10 min can delay banana ripening. Ethylene scrubbing, considered beneficial in storage of climacteric fruits and vegetables [8], may therefore be unnecessary with heated fruit. Hot air treatment of 35–40ºC inhibits ethylene synthesis within hours in both apples and tomatoes [19,20].

Present results suggested that hot water treatments 35ºC and 40ºC for 5 minutes was most suitable hot water treatments for delaying de-greening and hence delaying the ripening of seeni kesel banana during storage at ambient temperature (Fig. 1 and 2). Further, Fig. 1-B showed that the 40ºC hot water treatment for 10 minutes was also can be used for similar effect.

3.2 Taste and the Total Soluble Solid Content of Hot water Treated Seeni Kesel Banana

Average scores for taste of hot water treated banana were shown in Fig. 3. There were no significant differences of scores for taste among different hot water treatments compared to the control except 50ºC. There was a trend in reducing scores for taste after 40ºC. Therefore, even though there were no significant differences among taste of hot water treatments (at 45ºC) only up to 40ºC could only be used as hot water treatments to seeni kesel banana to have consumer preferable attributes.

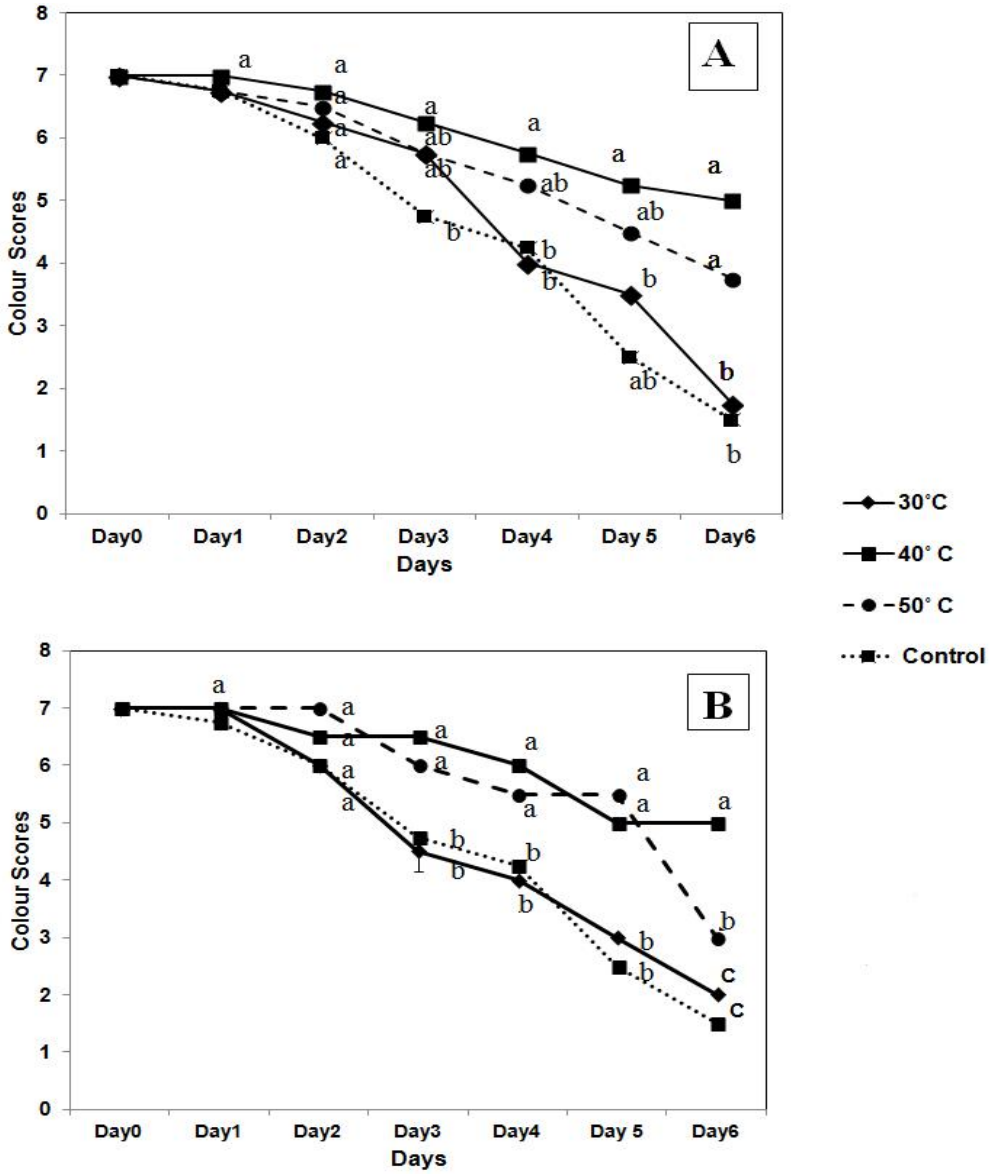

Fig. 1. Colour scores for banana peel during six days storage after 30, 40 and 50°C hot water treatments for 5 minutes (A) and for 10 minutes (B)

Hot water treatments indicated with same English letters in each day are not significantly different at p=0.05

Soluble solid content, which mainly represents the level of sugar, of hot water treated banana was presented in Fig. 4. These results indicated that the different hot water treatments were not affected to the level of soluble solid content in seeni kesel banana as there were no significant differences among heat treatments. This is a good indication that food taste and soluble solid content not affected badly in seeni kesel banana by hot water treatments up to 55ºC. Earlier studies also showed that soluble solids concentration is not affected by the heat treatment [22,24,25]. Therefore originality of food quality can be maintained though hot water treatment up to 55ºC according to the present results.

3.3 Suppression of Microbial Growth

In vitro microbial growth is presented in Fig. 5. Microbe colony growth was significantly high in control in everyday than that of all hot water treatments which showed highly significant low growth. Microbial growth of all hot water treated

banana was completely suppressed until day 2 of culture. From day 3 onward microbial growths increased significantly but not reached to the control. 40ºC and 45ºC heat treatments showed suppression of microbe growth in culture media until day 3 of culture period. 50ºC and 55ºC hot water treatments suppressed microbes in greater extent during culture observation period.

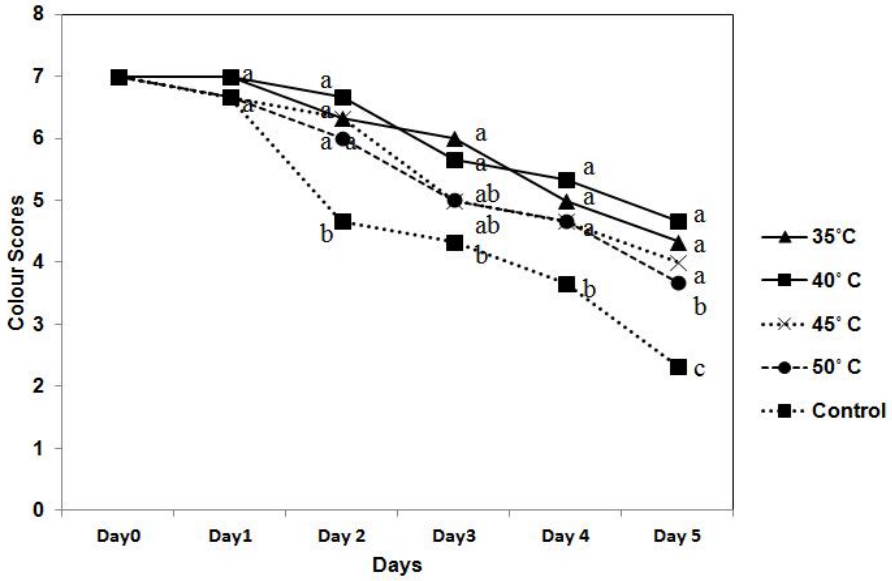

Fig. 2. Colour scores for banana peel during storage after 35, 40, 45 and 50°C hot water treatments for 5 minutes

Hot water treatments indicated with same English letters in each day are not significantly different at p=0.05

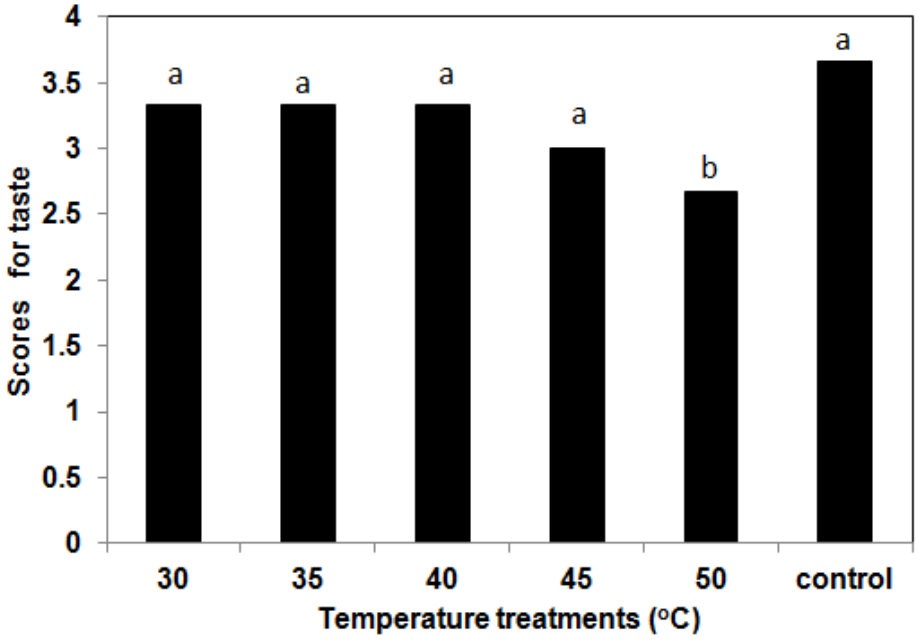

Fig. 3. Scores of banana taste after 35, 40, 45 and 50ºC hot water treatments for 5 minutes

Hot water treatments indicated with same English letters in each day are not significantly different at p=0.05

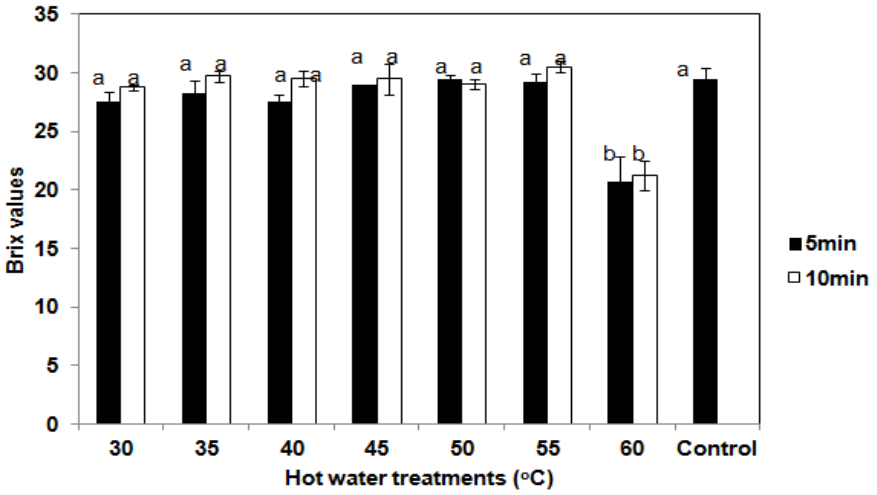

Fig. 4. Brix values of ripen banana after 35, 40, 45 and 50ºC hot water treatments for 5 and 10 minutes

Brix values indicated with same English letters are not significantly different at p=0.05
Error bars indicated ±SE of mean at P= 0.05 (n=6)

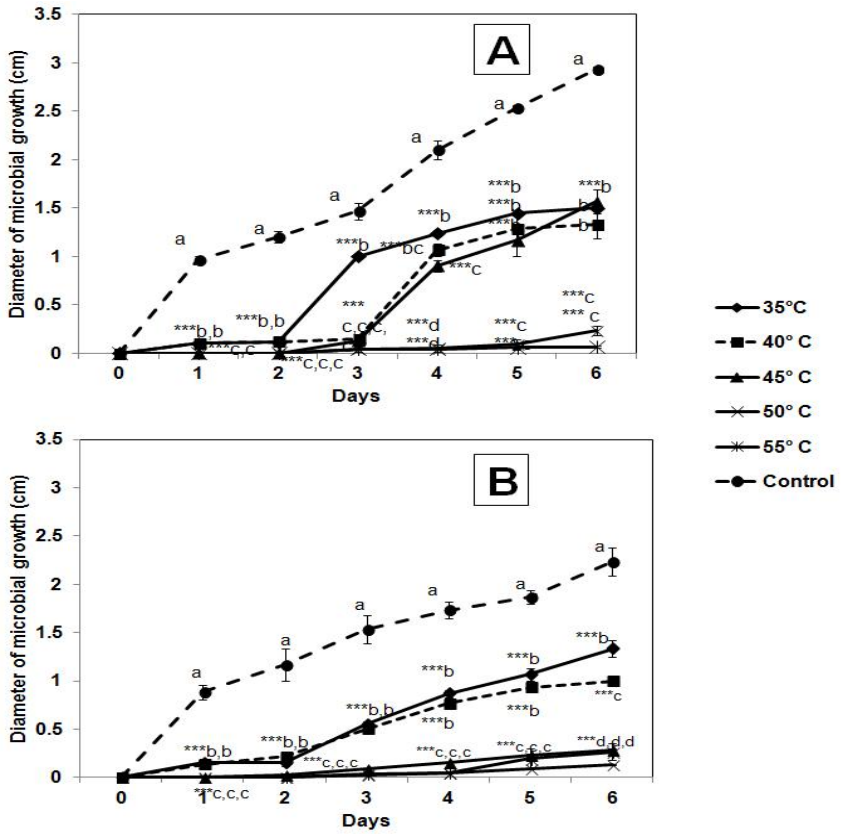

Fig. 5. Diameter of *in vitro* microbial growth from banana peel after 35, 40, 45, 50 and 55ºC hot water treatments for 5 minutes (A) and for 10 minutes (B)

*Error bars indicated ±SE of mean at P= 0.05 (n=6). Microbial growth: significant from normal control, ** P<0.001.*
Microbial growth Indicated with same English letters are not significantly different on each day

These results suggested that hot water treatment over 40ºC helps to suppress growth of microbes on fruit peel in greater extend compared to the control. It could be inference that the hot water treated banana can be stored suppressing postharvest disease occurring on fruit at least 4 days if treated more than 40ºC hot water. Even though the microbial growth starts later during storage it seems that it could not be vigor enough to cause damages to banana. The use of water dips at 38 to 60ºC for 2 to 60 min has been reported to control *in vivo* and *in vitro* spore germination and decay development of postharvest fungi in melons [26], papayas [27], strawberries [28] and tomatoes [29]. Both Couey [30] and Barkai-Golana and Phillips [31] have reviewed the results from these studies and others comprehensively [13]. Further, some scientists [32,33] suggested 50ºC hot water treatment as an optimum temperature for suppressing postharvest fungal diseases in banana varieties.

Most postharvest diseases are controlled by fungicides immediately after harvest as a spray or dip application. With the increasing awareness among consumers about fungicide residues the use of fungicide are becoming unpopular in the market. So, therefore effective non damaging physical treatment like hot water treatment is highly guaranteed for horticultural products in the market. Further, heat treatment is not only as delaying ripening, but also increase antioxidant levels in banana [23].

4. CONCLUSION

Present study suggested that hot water treatment 40ºC for 5 minutes was most suitable hot water treatments for delaying de-greening and hence delaying the ripening of seeni kesel banana during storage at ambient temperature. Food taste and soluble solid content not affected badly in seeni kesel banana by hot water treatments especially up to 40ºC. Microbial growth effectively controlled by hot water treatment over 40^{o}C. As with all this it can be concluded that hot water treatments 40ºC for seeni kesel banana is led to increase postharvest life without affecting the food quality of seeni kesel banana with possible health benefit too [23].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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