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Review on Effect of Hot Water Treatment on Physicochemical Characteristics of Banana Fruit

Review Article

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Abstract

Banana is very important perishable fruit produced in tropical and subtropical countries. It contains good nutritional value and bioactive components, which needed for healthy life. However, it has a short life because of its perishability. Quality deterioration is high after harvest since it is climacteric fruit and undergoes many biochemical changes during ripening stage. Thus, it requires special attention during postharvest handling in order to extend the shelf life and maintain postharvest quality of banana fruit. The application of appropriate postharvest techniques is crucially important to preserve the fresh quality of banana fruit after harvest. Heat treatment is one of these postharvest techniques, which has been used as a plant quarantine procedure in fresh fruit. Hot water treatment was shown to significantly lower the respiration and ethylene production rates of fresh produce. Physicochemical properties including peel color, total soluble solids, pH value, physiological weight loss, peel to pulp ratio can be influenced by hot water treatment. Peel color change was retarded and fruit firmness was maintained by hot water treatments. Furthermore, hot water dipping delayed fruit ripening by keeping fruit firmness, lowering the increase of pulp firmness (N), lower the continuous increase of total soluble solids (% brix), weight loss (%) and slowing the decrease in treatable acidity (TA) and slow retaining of pH fruit pulp during storage. Further research should be needed in combination of heat treatments with other postharvest technologies (such as ethylene suppressors, plant growth regulators, edible coatings, biological control agents and adequate packaging) could not only maintain physicochemical quality, but also improve the sensor quality of the commodity.

Keywords

Banana; Postharvest handling; Hot water treatment; Physicochemical; Fresh quality

Introduction

Banana is the second largest produced climacteric fruit after citrus, contributing about 16% of the world total production [1]. The fruits grow in clusters, each separate banana of the cluster being about 1 inch in diameter. Banana fruit requires about two and a half to four months after shooting before the fruit becomes ready for harvesting or a total about eight to twelve months after planting [2]. Three most common species of banana which are mostly grown in the world are Musa cavendishi, Musa paradisiaca and Musa sapientum [1]. It is one of top most fruit in the world

in production and as well as in consumption. Bananas are climacteric fruits which are artificially ripened regularly. Ripening process of banana can be divided into three distinct phases namely the pre-climacteric or green life stage, the climacteric and ripening stage and finally eat-ripe and senescence stage [3].

Banana contains high fiber content, and is capable of lowering cholesterol level and helps to relieve constipation and prevention of colon cancer [4]. Its high potassium content is found to be useful in the prevention of raising blood pressure and muscle cramp. Banana is said to prevent anemia by stimulating the production of hemoglobin in the blood [5]. Banana peel is hygienic and easy to remove packaging, making handling easy and convenient. The absence of seeds and availability throughout the year also contribute to its acceptance [5]. The consumption of banana is very important for health due to the high content of resistant starch, which acts in the body as food fiber [6,7]. Moreover, banana flour can be an important source of polyphenols, compounds considered as natural antioxidants [8]. As a climacteric fruit, the physiochemical changes that occur during banana ripening occur rapidly, resulting in color changes and notably perishable fruit after storage at room temperature. Banana peel color is a major criterion of the maturity and the grade of fruit maturity. Because bananas have a relatively short shelf life, postharvest treatments, and handling strategies are necessary to achieve optimal fruit maturity and to maintain quality [9].

Heat treatment is one of the most important postharvest techniques used as a plant quarantine procedure in mango, banana, apple, avocado, and litchi [10]. Over the last few years there has been increasing interest on the use of postharvest heat treatments. Heat treatment technologies are relatively simple and non-chemical alternative methyl bromide that can kill quarantine pests (insects, fungi) in perishable crops and used to control some postharvest diseases [10,11]. Hot water treatment is the best suitable medium for proper heat transfer in the inner intracellular parts for disinfestation pathogen. It is not only cleanses and disinfects but also prevents peel blackening of the banana during cold storage. Hot water was originally used for fungal control, but has been extended to disinfestation of insects. The desirable effects of hot water treatments linked with changes of physiological processes in reduction of chilling injury and delay of ripening processes by heat inactivation of derivative enzymes [11]. Moreover, it is crucially important in order to kill critical insect contaminations by controlling the onset of fungal decay [12] and by controlling the impedance of outer and inner mesocarp of fruits [13]. [14] Suggested that hot water treatments 35ºC and 40ºC for 5 minutes is most suitable hot water treatments for delaying de-greening and hence, increase postharvest life of seeni kesel banana without affecting consumer preference during storage at ambient temperature. Therefore, the aim of this review is to summarize different hot water treatments and discuss its effect on physicochemical characteristics of banana fruit.

Effect of Hot Water Treatment on Physico-chemical Characteristics of Banana

Effect of hot water treatment on banana peel color

Heat treatment increase the lightness value of the bananas peel and the treatment duration is responsible for increasing the lightness value of banana peel and greenness (-a value) of banana peel also increased with heat treatment. Dipping in water might have caused removal of surface washing and removal of dirty, which increase the lightness and greenness values. [15] Observed that hot water dipping at 52°C for 2 minutes and 55°C for 1min produced the cleaner and glossier mandarin fruit with bright reddish yellow color as compared to untreated fruits. Hue values of banana fruits dipped in 45°C water for 5 and 10 min, and untreated fruit sharply declined indicating increased degree of yellowing. In contrast, fruits dipped in 45°C water for 15 min or in 50°C water for 10 min maintained higher hue values and greener color than the other treatments. Hot water treatment at 50°C for 10 min was more effective maintaining higher hue value and delaying yellowing than at 45°C for 15 minutes [16]. (Figure 1) represents change in hue angle color of banana fruit dipped in hot water at 45°C for 5, 10 and 15 min, and 50°C for 10 minutes during 12 days of storage.

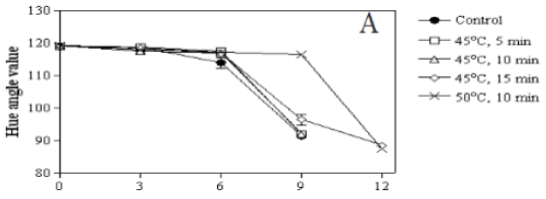

Figure 1: Changes in hue angle colour (A) of banana fruit dipped in hot water at 45°C for 5, 10 and 15 min, and 50°C for 10 min. Controls were dipped in room temperature water.

[17] Described the different stages of ripening related with pigment changes within the peel of banana. The visual

descriptions for the different stages include:- 1= Green, 2= Green with trace of yellow, 3= Green and yellow both occur, 4=Yellow with trace of green, 5= Green tip, i.e., when the fruit is full yellow except at the extreme flower end , 6= Completely yellow colour , 7= Full ripe, i.e., clear yellow with signs of dark marking (Flecking), 8= Flecked, i.e., blackening. During ripening, colour development depends on external conditions which are important quality parameters of fruit for marketing [18]. Generally, banana peel color changes from green to yellow due to chlorophyll degradation, which subsequently reveals the yellow carotenoid pigments [19,20]. The stage of colouration is an excellent indicator of the probable composition of banana fruit. Lightness ('L') value, greenness ('a') value and yellowness ('b') value was a useful method to determine the development of peel colour of banana and could be a useful replacement of subjective method of colour charts [21]. The most retailers prefer fruit at yellow colour [22]. Peel colour change from green to yellow because of chlorophyll degradation which is the most important eating criterion used by consumers to determine fruit ripening [23].

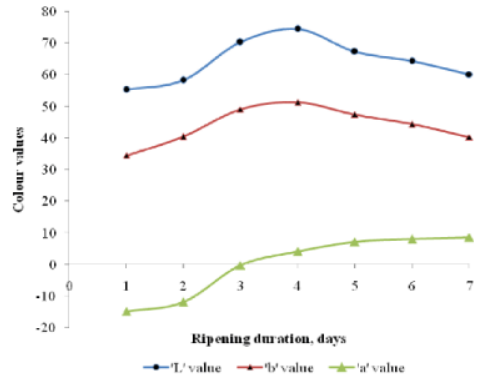

Figure 2: Changes in lightness ('L'), greenness ('a') and yellowness ('b') value during ripening of banana fruit (Shahir, S. and Visvanathan, R., 2014)

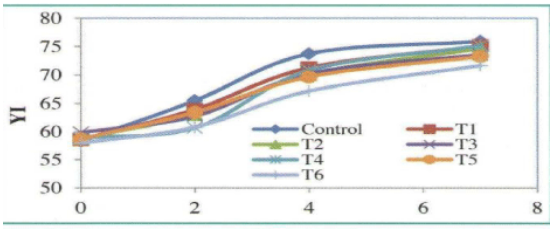

Figure 3: Variation in yellowness index of treated and untreated banana with days of storage (Amin et al., 2016).
T1= hot water treatment at 40oC for 30 minutes; T2= hot water treatment at 40oC for 45 minutes; T3= hot water treatment at 40oC for 60 minutes; T4=hot water treatment at 45oC for 30 minutes; T5= hot water treatment at 45oC for 45 minutes and T6= 45oC at 45 for 60 minutes.

(Figure 2) mentions the changes in colour values ('L' 'a' 'b') of banana fruit during ripening process as well as variation in yellowness index of treated and untreated banana with days of storage is explained in (Figure 3).

Effect of hot water treatment on banana pulp firmness

Fruit firmness decreased with storage faster in control than treated fruit with hot water. Decreasing trend in fruit pulp firmness during storage was due to solubilization of peptic substances in the cell wall and middle lamella, which was reported by [24]. Samples of banana fruit were dipped for 10 minutes in different water treatments at 40°C, 50°C and 60°C resulted the highest values for moisture content (%), pulp firmness (N), pulp to peel ratio of banana fruit during storage.

Among dipped in water at 45°C for 5, 10 and 15 min and 50°C for 10 min, 50°C for 10 min was most effective in delaying firmness loss or softening. The fruit remained firm for 9 days and softened 3 days later whereas other hot water treated fruit softened to the level of the control after 6 days of storage. Thus, hot water treatment at 50°C for 10 min is effective in delaying fruit softening and could be used as a treatment to extend the firm-fruit life for export purposes [25] and [26] found that hot water treatment inhibited color development in melons and tomatoes and delayed their ripening as well during storage. [11] Reported that the reduction in fruit softening caused by hot water treatment was caused by the inhibition of pectin cell wall solublization, a reduced level of cell wall degrading enzyme activity and inhibit ethylene production due to a reduction in the activity of ethylene forming enzyme. (Figure 4) shows changes in fruit firmness (C) of banana fruit dipped in different hot water temperatures for different time durations.

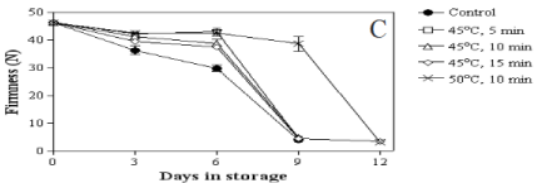

Figure 4: Changes in fruit firmness (C) of banana fruit dipped in hot water at 45°C for 5, 10 and15 min, and 50°C for 10 min.

Controls were dipped in room temperature water [16].

Firmness is a very important quality parameter of banana. The changes in firmness of banana pulp from hard

to consumption ripe are obvious change that happens throughout storage period. In case of firmness change, the pulp becomes softer and sweeter will increase. Therefore, the characteristics aroma is created. These results may indicate that the firming effect is accompanied by improved water holding capacity due to a more cross-linked pectin network. Additionally, higher water holding capacity could be related to increased firmness due to higher turgor pressure which is supported by higher moisture content and hardness attributes obtained with infiltration treatment. [24] Suggested that the pulp firmness of Basari banana variety ranged between 4.63 to 5.11N. The highest banana fruit pulp firmness with 5.11N was observed under T3 (50°C hot water dip for 10 minutes), followed by T2 (40°C hot water dip for 10 minutes), and T1 (untreated fruit); whereas the minimum pulp firmness with 4.63 N was observed under treatment T4 (60°C hot water dip for 10 minutes). Moreover, the average initial pulp firmness of banana was observed to be 7.04 N, which decreased with increasing days of storage. The average decrease in pulp firmness of Basari banana after 15 days was observed to be 2.15 N. (Table 1) represents the effect of different hot water treatment on pulp firmness of banana fruit during 15 days of storage.

Table 1: Effect of different hot water treatments on pulp firmness (N) of banana fruit.

Treatment	Storage period				Mean
	0 day	05 day	10 day	15 day	
T1	7.03	5.89	4.21	2.09	4.81^{C}
T2	7.06	6.02	4.52	2.18	4.95^{B}
T3	7.06	6.35	4.71	2.31	5.11^{A}
T4	7.01	5.47	4.02	2.00	4.63^{D}
Mean	7.04^{A}	5.93^{B}	4.37^{C}	2.15^{D}	

T1= untreated fruit (control), T2= 40°C hot water dip for 10 minutes, T3= 50°C hot water dip for 10 minutes and T4= 60°C hot water dip for 10 minutes

Effect of hot water treatment on physiological weight loss (%) banana fruit

The level of weight loss at each observation point to be varied between each treatment, with a tendency to increase from the beginning to the end of the treatment. The longer the storage times of the fruit, the higher the weight loss. The weight loss value was obtained from the average of three replicates that started with banana fruits with different initial weight, and this could cause variations in the data measurement. Physiological weight loss of fruit is a direct result of water loss which is due to external and internal factors such as temperature, relative humidity, and peel permeability [26]. However, the loss rate was high in untreated banana fruits due to high water loss. Losses of water reduce turgor which contribute to softness fruit and accelerate the ripening of banana fruit [27]. The rate of water loss depends on external factors (temperature, relative humidity (RH), air movement and atmospheric pressure) and internal factors that modulate the rate of water loss include morphological and anatomical characteristics (surface-to-volume ratio) and surface injury [28]. At ambient relative humidity of 95-100%, fruit lose little or no moisture and the ripening period is maximal. As humidity decreases, the rate of water loss increases and the ripening period reduces. [29] Reported that relative humidity delayed ripening and produced good eating quality of 'Cavendish' banana fruit compared with those held at low humidity. Furthermore, the greater the surface area to volume ratio has the shorter postharvest life because large fruit lose less water than small fruit and fruit with thin skins lose more water. In addition, higher peel permeability leads to a higher rate of water loss and higher density of stomata may lead to a higher rate of water loss, which in turn can accelerate ripening [26]. Thus, ripening and post-harvest handling methods had significant effects on physiological weight loss were recorded at 15 days of storage according to shown in (Table 2).

Table 2: Effect of different hot water treatments on weight loss of banana fruit during15 days of storage (Kaka et al; 2019)

	Storage period				
Treatment	0 day	05 day	10 day	15 day	Mean
T1	0	5.72	13.5	15.18	8.60^{B}
T2	0	5.43	12.6	14.40	7.60^{D}
T3	0	5.26	11.3	13.84	8.11^{C}
T4	0	6.10	14.3	16.10	9.13^{A}
Mean	0.00^{D}	5.63^{C}	12.93^{B}	14.88^{A}	

T1=control; T2= 40°C hot water dip for 10 minutes, T3=50°C hot water dip for 10minutes and T4=60°C hot water dip for 10 minutes.

Effect of hot water treatment on total soluble solids (% Brix)

The total soluble solids of banana fruit was increased during storage of banana fruit due to breakdown of starch into soluble sugars while an increase of cell wall solubility allows nutrients and water to pass in and out of the cells [30]. [31] suggested that bananas treated with combinations of 53°C for 9 min or 55°C for 7 min obtained higher lightness (L*), TSS, total sugars, acidity and β-carotene than untreated fruit; however, the vitamin C content of the treated bananas was reduced . The effect

of different hot water treatments on total soluble solids of banana fruit within 10 days of storage has shown in (Table 3).

Table 3: Effect of different hot water treatments on total soluble solid (°Brix) banana fruit.

	0-day	2nd day	4th day	7th day	10th day
Control	5.2^{a}	13.4^{a}	16.8^{a}	17.6^{a}	17.6^{a}
T1	5.2^{a}	13.2^{ab}	16.2^{b}	17.2^{ab}	17.4^{b}
T2	5.8^{a}	13.2^{ab}	15.4^{c}	16.4^{c}	16.8^{c}
T3	5.4^{b}	12.8^{b}	16.0^{b}	17.0^{b}	17.0^{bc}
T4	5.8^{c}	13.2^{b}	16.2^{b}	16.8^{c}	17.2^{b}
T5	5.6^{bc}	12.6^{c}	14.4^{d}	15.8^{d}	16.8^{c}
T6	5.8^{c}	11.4^{c}	13.6^{e}	15.0^{e}	16.4^{d}

Where, T1= hot water treatment at 40°C for 30 minutes; T2= hot water treatment at 40°C for 45 minutes; T3= hot water treatment at 40°C for 60 minutes**;** T4=hot water treatment at 45°C for 30 minutes; T5= hot water treatment at 45°C for 45 minutes and T6= 45°C at 45 for 60 minutes**.** Letters of same each column is not significantly different at $p < 0.01$.

[14] reported 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. Therefore, originality of food quality can be maintained though hot water treatment up to 55ºC. (Figure 5) shows brix values of ripen banana after 30, 35, 40, 45, 50 55 and 60 ºC hot water treatments for 5 and 10 minutes.

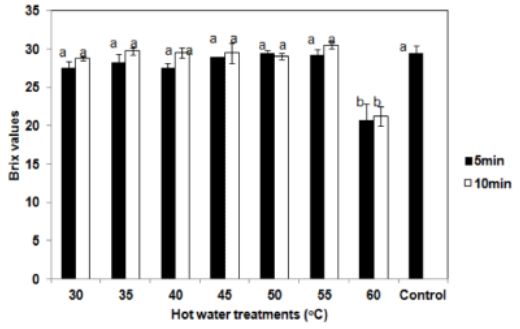

Figure 5: Brix values of ripen banana after 30, 35, 40, 45, 50, 55 and 60ºC hot water treatments for 5 and 10 minutes. Brix values indicated with same English letters are not significantly different at p=0.05, Error bars indicated ±SE of mean at P= 0.05 (n=6) (Dissanayake et al; 2015)

Total soluble solids content is increased with storage period. The degree of increasing in total soluble solid in different postharvest treatments might be due to the modified internal atmosphere and physiological aspects of banana fruits, decrease respiration and metabolic processes, which involve in increasing TSS at different magnitudes, The different storage treatments used in the investigation showed statistically significant variations in relation to percent TSS at all ripening stages. The effect of different postharvest treatments on total soluble solid of banana during storage and ripening are mentioned in (Table 4).

Table 4: Effects of different postharvest treatments on TSS of banana during storage and ripening.

Treatments	TSS at different days of storage		
	3 day	6 day	9 day
T1	15.00	27.11	25.66
T2	14.61	25.88	26.33
T3	15.5	26.05	26.77
T4	13.44	17.55	23.11
T5	17	22	25.61
T6	16.88	22.66	23.83
T7	16.77	22.27	24.33
T8	14.96	25.11	26.11
LSD (0.05)	0.74	0.98	0.92
LSD (0.01)	1.06	1.40	1.32
Level of significance	**	**	**
CV %	4.46	3.89	3.43

** = Significant at 1% level of probability, ND=Statistical analysis was not done. T1 = Control,*
T2= Cooling at 5°C for 30 minutes, T3 =Cooling at 10°C for 30 minutes, T4 = Storage at 15°C, T5 = Hot water treatment at 50°C for 5 minutes, T6 = Modified atmosphere packaging without perforation, T7 = Modified atmosphere packaging with perforation and T8 =Modified atmosphere packaging with KMnO4.

Effect of hot water treatment on pH and Titratable Acidity of banana

The increase in titratable acidity and decrease of pulp pH occurs until peel colour stage three and then acidity drops and pH increases and this coincides with the climacteric respiration [32]. However, number of days to reach maximum titratable acidity may vary based on difference in ripening methods. Decrease in titratable acidity was due to the conversion of starch to simple sugars and increasing of total soluble solids in banana pulp during

ripening. [33] Reported that high temperature increases the rate of respiration in fruits results subsequently to the breakdown of the inner tissues. The effect of different hot water treatments on titratable acidity of banana is mentioned in (Table 5).

Table 5: Effect of different hot water treatments on the titratable acidty of banana during storage (Kader, 2005)

Treatment	Storage period				Mean
	0 day	05 day	10 day	15 day	
T1	0.71	0.53	0.40	0.28	0.48^{C}
T2	0.80	0.58	0.47	0.33	0.55^{B}
T3	0.72	0.65	0.52	0.37	0.57^{A}
T4	0.73	0.50	0.32	0.21	0.44^{D}
Mean	0.74^{A}	0.57^{B}	0.43^{C}	0.30^{D}	

T1=control; T2= 40°C hot water dip for 10 minutes, T3=50°C hot water dip for 10minutes and T4=60°C hot water dip for 10 minutes.

[24] reported that highest banana pulp pH was observed at 60°C hot water dip for 10 minutes followed by 40°C hot water dip for 10 minutes, whereas lowest pulp pH was observed under treatment of 50°C hot water dip for 10 minutes. Pulp pH was increase with storage period. The effect of different hot water treatments on pH of banana pulp has been shown in (Table 6) [34-38].

Table 6: Effect of different hot water treatments on the pH of banana pulp (Kaka et al; 2019)

Treatment	Storage period				Mean
	0 day	05 day	10 day	15 day	
T1	4.58	5.42	6.05	6.30	5.59^{B}
T2	4.74	5.39	5.82	6.00	5.49^{C}
T3	4.65	5.29	5.57	5.75	5.32^{D}
T4	4.52	5.48	6.32	6.81	5.78^{A}
Mean	4.62^{D}	5.40^{C}	5.94^{B}	6.22^{A}	

T1=control; T2= 40°C hot water dip for 10 minutes, T3=50°C hot water dip for 10minutes and T4=60°C hot water dip for 10 minutes.

Conclusion

Heat treatment technologies are relatively simple and non-chemical alternative methyl bromide that can kill quarantine pests in perishable crops and reduce postharvest loss fresh produce. Hot water treatment is the best suitable medium for proper heat transfer in the inner intracellular parts for disinfestation pathogen and controls some postharvest diseases. It is not only cleanses and disinfects but also prevents peel blackening of the banana during cold storage. Time and temperature combination are the major factor during hot water treatment in order to enhance the freshness quality and extend the shelf life of bananas. Fresh produce when treated with hot water resulted in better quality, which was significantly different from those fresh produce which were untreated. Furthermore, it was also observed that physicochemical parameters of treated banana fruit include change in peel color, physiological weight loss, total soluble solid, pulp pH increased with increasing during storage and ripening; whereas firmness and titratable acidity were decreased during banana ripening. Hot water treatment technique is very important method to improve the quality attributes of banana along with increasing its shelf life. 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. Banana fruit ripening can be delayed effectively by application of hot water treatments such as 40°C for five minutes. These treatments are not negatively effect on fruit taste, brix value.

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