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Influence of hot water treatment to quality properties of pineapple (*Ananas comosus*) fruit during storage

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Abstract

Pineapple (*Ananas comosus*) was a non-climacteric fruit popularly distributed in Vietnam and other tropical regions. It was highly preferred by great appearance, wonderful texture, special flavour and perfect nutritional value. Moreover, it was also a good source of minerals, vitamins and antioxidants beneficial for human health. In harvesting season, it was highly perishable under ambient storage due to its high metabolic and moisture content resulting in quality degradation. This research evaluated the possibility of hot water treatment to the retention of quality attributes during storage. Pineapple fruits were dipped in hot water at different times and temperatures 30/35 (as control), 50/45, 52/40, 54/35, 56/30, 58/25, 60/20, 62/15 (°C/s). They were drained for 30 mins and stored at the ambient condition at the relative humidity of 85-90% for 15 days. In 3 day-interval, these fruit groups were taken to evaluate weight loss, firmness, decay index, total soluble solids (TSS), ascorbic acid. Results showed that there was a significant difference between the control and 7 treated groups. Pineapple fruits treated by hot water at 56/30 (°C/s) showed the lowest weight loss (0.15±0.05 to 1.34±0.01%), the lowest decay index (1.03±0.02 to 1.63±0.02), the most firmness (19.43±0.00 to 18.63±0.03 N), the highest TSS (24.35±0.02 to 23.01±0.01^{o}Bx), the highest ascorbic acid content (18.59±0.01 to 17.79±0.02 mg/100 g). Application of hot water submergence provided an alternative to chemical treatment to extend pineapple stability during storage and improve its marketability in distribution.

1. Introduction

Pineapple (*Ananas comosus*) was a non-climacteric fruit commonly harvested at optimum maturity before consumption (Lobo and Yahia, 2016). It was an important fruit crop with excellent sense, precious nutritional proximate, phytochemical and antioxidant constituent (Hossain and Rahman, 2011; Nguyen *et al.*, 2019). Pineapple fruit had various capacities to convert into functional food (Nguyen *et al.*, 2020). Its pulp had an obvious yellow colour, delicious taste, textural filament, rich in carotene, vitamin C, vitamins B and B_2 (Lin and Zhao, 2007; Minh, 2020). Bromelain as a hydrolyzed enzyme in pineapple was useful for the digestive system in stabilizing body weight and equilibrium nutrition (Vipul *et al.*, 2019). It could be utilized for treatments against acute sinusitis, sore throat, arthritis and gout (Tanmay *et al.*, 2018). Pineapple fruit was highly susceptible and perishable at room condition. Physical damage, physiological and biochemical disturbance frequently happened at harvest and post-harvest handling steps such as transport, distribution at retail markets and consumer handling at home (Menouwesso *et al.*, 2014). Physiological and biochemical disturbances were occurred by respiration, ethylene production and ripening. Chilling injury was the most problem of pineapple fruit during storage (Chairat *et al.*, 2017). Major spoilage microorganisms responsible for pineapple decay were identified *Saccharomyces, Candida* and *Debarromyces* species. Under ambient temperature, they attacked pineapple fruit as early as the 3rd day of storage hence fruit completely deteriorated on the 15th day of storage (Joseph-Adekunle *et al.*, 2010). Pineapple fruit stored at 1^{o}C with 88±2% relative humidity had an extended shelf life of up to 21 days (Chowdhury *et al.*, 2019). The low temperature could be considered as a mono-effective strategy to maintain quality and extend the stability of agricultural products during preservation (Dolhaji *et al.*, 2020). However, cool storage was not always available in some circumstances due to the huge cost in construction and operation of the cool store. In order to prolong its stability for distribution and consumption, chemical treatment could be effectively applied via coating or spraying. However,

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chemical residue was a big concern to human health. Physical treatment was revealed as a promising alternative to maintaining fruit quality. Different literature mentioned the preservation of pineapple fruit by controlling temperature and relative humidity during storage (Tasneem, 2004), proper postharvest treatment and packaging (Anwar and Malik, 2007).

Hot water treatment was applied on fruit for not only fungal and insect management but also microbial disinfestation (Mustafa *et al.*, 2005). It successfully protected against post-harvest decay and maintained the storage quality of different crop products (Ferguson *et al.*, 2000; Fallik *et al.*, 2001; Vicente *et al.*, 2002; Trierweiler *et al.*, 2003; Lana *et al.,* 2005; Spadoni *et al.*, 2015; Kabelitz and Hassenberg, 2018). Hot water treatment was commonly applied in food factories. It was really beneficial as an environmentally-economically-friendly technique to control fruit decay without chemical residue. It was especially appropriate for organic manufacture (Fallik, 2004; Maxin *et al.*, 2014). Hot water as a versatile thermal transfer medium was properly circulated over the fruit surface, immediately established a uniform temperature configuration (Couey, 1989). Short processing time was very important in large scale production. Therefore, hot water treatment should be conducted at a relatively high temperature (40-80°C) in a quick manner (second to a few minutes). Straight impact of hot water on pathogen-related to an accumulation in intracellular reactive oxygen species, mitochondrial disorder and a reduction in ATP; and on the owner, by improving the guard-associated enzyme phenylalanine ammonia-lyase in the fruit (Liu *et al.*, 2012). Heat treatment limited rotten on the fruit skin by sparking the local demonstration of protective–associated proteins (Li *et al.*, 2013). Hot water soaking at 53°C in 3 mins washed the peel off the muskmelon fruit, drained the epicuticular waxes, spread and closed stomata, improved the reaction of the protective–involved enzymes phenylalanine ammonia-lyase, cinnamate-4-hydroxylase, 4-coumarate:coaligase, polyphenoloxidase and peroxidase (Yuan *et al.*, (2013).

In order to maintain the quality property and extend the shelf life of pineapple fruit, the objective of our study was to verify the postharvest treatment using hot water submergence to maintain the quality characteristics of pineapple fruit during storage and thereby prolong its marketing value.

2. Materials and methods

2.1 Materials

Pineapple fruits were harvested from a farm in Hau Giang province, Vietnam. After collecting, they were immediately moved to the laboratory within the day of harvest for experiments. They were sorted in uniformity and had no defects, kept in plastic trays. The hot water tank was fitted with a heating coil and re-circulation pump. One hundred and fifty litres of water was used for each treatment batch. Chemical reagents such as 2,6-dichlorophenol indophenol, oxalic acid, sodium carbonate were all analytical grades purchased from Ho Chi Minh City, Vietnam. Lab utensils and equipment included digital weight balance (model WA-2Y), texture penetrator (model TA-XT2), hand-held refractometer (model 10419) and biuret (from Sigma-Aldrich).

2.2 Methods

These fruits were separated into eight groups: group 1st was dipped in fresh water at 30/45 (°C/s) as control, other groups were individually dipped in hot water in different conditions (50/45, 52/40, 54/35, 56/30, 58/25, 60/20, 62/15, °C/s). The control and treated fruits were drained for 30 min and stored at the ambient condition at the relative humidity of 85-90% for 15 days. In 3 day-interval, these fruit groups were taken to evaluate weight loss (%), firmness (N), decay index, total soluble solid (°Bx), ascorbic acid (mg/100 g). The water temperature was constantly stabilized within ±0.5°C of the experimental temperature by an electronic thermostat and probe.

2.3 Physicochemical analysis

Weight loss (%) was estimated as the variation of weight at the initial and the interval time of sampling. Firmness (N) was evaluated by texture penetrator. Decay index was evaluated by visual symptoms of fruit from totally raw (1 score), decay 5-10% (2 scores), decay 10-30% (3 scores), decay 30-50% (4 scores), damage over 50% (5 scores). Total soluble solid (°Bx) was quantified by a hand-held refractometer. Ascorbic acid content (mg/100g) was measured by the volumetric method using a 2,6-dichlorophenol indophenol visual titration method described by AOAC (2005). About 1 mL of the working standard solution was pipetted into a 20 mL conical flask. After, 2 mL of 4% oxalic acid was titrated against the dye (V_1, mL). The final point was the appearance of the pink pigment. The amount of dye titrated was equivalent to the amount of ascorbic acid. The sample was weighed (M, g) and filled with 4% oxalic acid to volume (20 mL), separated by centrifugation. Take 1 mL of this supernatant with 2 mL of 4% oxalic acid and then titrate against the dye (V_2, mL).

$$\text{Ascorbic acid content (mg/100g)} = \frac{0.5 \times V_2 \times 20 \times 100}{V_1 \times M}$$

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2.4 Statistical analysis

The experiments were run in triplicate with different groups of samples. The data were presented as mean ± standard deviation. Statistical analysis was performed by the Statgraphics Centurion version XVI.

3. Results and discussion

Transpiration and respiration were the major cause of weight loss in fruits and vegetables. Table 1 shows the weight loss of the control and hot water treated pineapple fruit. The control group at 30/45 (°C/s) had the highest percentage of weight loss (2.78±0.04 to 10.79±0.03%), meanwhile, the treated samples at 56/30 (°C/s) had the lowest weight loss (0.15±0.05 to 1.34±0.01%). This could be due to the limitation of metabolism and respiration rate. A sharp increase in cumulative weight loss of the control group could be due to a high respiration rate. Hot water negatively affected cell wall degrading enzyme activity, dysfunction of the ethylene synthesis enzyme and vulnerability of ripening related RNA synthesis (Safdar, 2009). Okra dipped in hot water at 50°C for 1 min decreased weight loss (Ngure *et al.*, 2008). Hot water treatment retarded weight loss of tomato over control during storage (Safdar, 2009). The dragon fruit treated with hot water at 35°C for 60 mins had the lowest percentage of weight loss (Lum and Norazira, 2011). Bananas dipped in hot water at 50°C for 10 mins had a low respiration rate (Varit and Songsin, 2011). Banana treated with hot water at 55°C for 5 mins reduced by 70% weight loss compared to those of untreated ones (Mohammad and Mosharraf, 2013). Mango treated with hot water 50°C for 11 mins and kept in 7°C resulted in less weight loss (Abdul-Rahaman *et al.*, 2014). Hot water dipping at 50°C for 20 mins slowed down the ripening rate by retarding the tomato fruit softening and weight loss for 11 days of storage (Safiyaa *et al.*, 2016). Hot water treatment at 55°C in 7 mins resulted in a decreased weight loss of tomato fruit (Manal *et al.*, 2019). Rapid hot water treatment (59-60°C for 35 s) was superior to conventional hot water treatment (52- 55°C for 10 mins) in respect of weight loss reduction (Pasilan *et al.*, 2020). Mango fruit preliminarily treated with hot water, significantly reduced fruit weight loss during 7 days of storage at ambient conditions (Pholoma *et al.*, 2020).

Firmness was one of the key quality variables of fruit during post-harvest storage. Hot water treatment 56/30 (°C/s) fruit was the most firm (19.43±0.00 to 18.63±0.03 N), while the control 30/45 (°C/s) was the least hard (15.03±0.04 to 10.75±0.01 N). The firmness of all control and the treated group decreased during 15 days of storage (Table 2). Degradation of protopectin into water-soluble pectin, movement of symplastic soluble solids into intercellular spaces, reduction in cellulose crystallinity, diffusion of ions out of the cell wall, or cell wall thinning were major causes of fruit softening (Toivonen and Brummell, 2008; Liu *et al.,* 2017). Hemicellulose and cellulose were also commonly decomposed during fruit preservation leading to less firmness (Chen *et al.*, 2017). The softening process was derived from the hydrolysis of cell wall-degrading enzymes like polygalacturonase, pectin methylesterase, cellulase, β-galactosidase, and α--arabinofuranosidase (Gwanpua *et al.*, 2016; Lu *et al.*, 2018; Yoo *et al.*, 2018). Hot water treatment resulted in the inhibition of pectin cell wall hydrolysis (Lurie, 1998). Hot water treatment permitted demethylation of pectin to release anionic carboxyl groups wherein calcium can interact to establish a salt bridge. This bridge protected the fruit from cell wall-degrading enzymes (Sams *et al.*, 1993). However, a long treatment duration also negatively affected pectin functionality (Diaz *et al.,* 2007). Hot water at 46.5°C for 45 mins led to higher firmness of mango (Nyanjage *et al.*, 1998). Treated tomatoes in hot water at 42°C was better firm than untreated ones (Safdar, 2009). Dragon fruit submerged in hot water at 35°C presented the highest firmness (Lum and Norazira, 2011). Bananas dipped in hot water at 50°C for 10 mins had higher firmness compared to control (Varit and Songsin, 2011). Nectarine dipped in hot water at 48°C

Table 1. Effect of hot water treatment (°C/s) to weight loss (%) of pineapple during storage

Hot water (°C/s)	3	6	9	12	15
30/45	2.78±0.04^{a}	4.59±0.02^{a}	6.12±0.07^{a}	8.03±0.02^{a}	10.79±0.03^{a}
50/45	1.31±0.06^{bc}	2.35±0.05^{bc}	2.39±0.02^{bc}	2.87±0.04^{bc}	3.05±0.05^{bc}
52/40	0.84±0.03^{cd}	1.67±0.04^{cd}	1.69±0.01^{cd}	2.12±0.05^{cd}	2.43±0.02^{cd}
54/35	0.36±0.07^{de}	0.81±0.03^{de}	1.00±0.05^{de}	1.35±0.03^{de}	1.77±0.06^{de}
56/30	0.15±0.05^{e}	0.49±0.02^{e}	0.75±0.04^{e}	0.98±0.07^{e}	1.34±0.01^{e}
58/25	0.54±0.04^{d}	1.23±0.06^{d}	1.32±0.02^{d}	1.79±0.05^{d}	2.09±0.04^{d}
60/20	1.02±0.06^{c}	1.99±0.03^{c}	2.02±0.03^{c}	2.45±0.04^{c}	2.78±0.05^{c}
62/15	1.81±0.02^{b}	2.68±0.05^{b}	2.81±0.06^{b}	3.21±0.02^{b}	3.41±0.03^{b}

Values are presented as mean±SD, n = 3. Values with the same superscript within the same row are not significantly different (α = 5%).

Table 2. Effect of hot water treatment (°C/s) to firmness (N) of pineapple during storage

Hot water (°C/s)	3	6	9	12	15
30/45	15.03±0.04^{e}	14.29±0.01^{e}	13.14±0.02^{e}	12.01±0.05^{e}	10.75±0.01^{e}
50/45	17.75±0.01^{cd}	17.75±0.03^{cd}	17.33±0.00^{cd}	17.02±0.02^{cd}	16.69±0.03^{cd}
52/40	18.46±0.03^{bc}	18.32±0.02^{bc}	18.01±0.03^{bc}	17.77±0.01^{bc}	17.30±0.02^{bc}
54/35	19.04±0.05^{ab}	18.96±0.00^{ab}	18.69±0.01^{ab}	18.49±0.03^{ab}	18.17±0.05^{ab}
56/30	19.43±0.00^{a}	19.27±0.02^{a}	19.03±0.04^{a}	18.80±0.00^{a}	18.63±0.03^{a}
58/25	18.79±0.03^{b}	18.61±0.05^{b}	18.34±0.02^{b}	18.02±0.01^{b}	17.86±0.02^{b}
60/20	18.02±0.02^{c}	18.04±0.03^{c}	17.68±0.00^{c}	17.35±0.05^{c}	17.04±0.04^{c}
62/15	17.48±0.04^{d}	17.49±0.01^{d}	17.01±0.03^{d}	16.73±0.02^{d}	16.38±0.01^{d}

Values are presented as mean±SD, n = 3. Values with the same superscript within the same row are not significantly different (α = 5%).

for 6-12 mins had higher firmness during 2 weeks of storage at 0°C (Jemric and Fruk, 2013). Mango treated by hot water 50°C in 11 mins and kept in 7°C resulted in better firmness (Abdul-Rahaman *et al.*, 2014). Hot water treatment at 55°C in 7 mins increased the firmness of tomato fruit (Manal *et al.*, 2019). Rapid hot water treatment (59-60ºC for 35 s) was superior to conventional hot water treatment (52-55ºC for 10 mins) in respect of better firmness (Pasilan *et al.*, 2020). Mango fruit preliminarily treated with hot water significantly maintained firmness during 7 days of storage at ambient conditions (Pholoma *et al.*, 2020).

Fruit decay was commonly derived from the invasion of rotten-relating pathogens as it caused the most harvest loss in most horticultural crops. The growth of microorganisms requires favourable environmental conditions. Table 3 presents the decay index of the control and treated samples. The control group at 30/45 (°C/s) had the highest decay index (2.51±0.01 to 4.79±0.02), meanwhile, the treated samples at 56/30 (°C/s) had the lowest decay index (1.03±0.02 to 1.63±0.02). Fungal and bacterial infections induced fruit decay where temperatures 28 to 30°C was favourable for the fungal and bacterial proliferation (Maqsood *et al.*, 2014). Hot water treatment created a sharp reduction in decay and retention of numerous quality attributes (Varit and Songsin, 2011). The main principle of hot water treatment in mitigation of fruit decay was a straight germicidal impact on pathogens, flowing and covering the allocation of cuticular waxes on the fruit skin, retarding the location of pathogen intrusion. Hot water dipping (55°C for 5 mins) on mango induced resorcinol formation in restraining the pathogenic proliferation (Kobiler *et al.* 1998). Hot water at 46.5°C for 45 mins led to lesser severity of diseases on mango (Nyanjage *et al.*, 1998). Mango had better resistance to decay by hot water at 45°C for 30 mins (Jacobi *et al.*, 2000). Hot temperatures at a shorter time were believed to sanitize and improve the resistant capacity of fruit to pathogens (Pavoncello *et al.* 2001). Hot water dip at 53°C for 6 hrs minimized chilling injury and decay on orange (Mustafa *et al.*, 2005). Mango submerged in hot water at 50°C for 5 mins effectively retarded postharvest disease (Mansour *et al.*, 2006). Okra dipped in hot water at 50°C for 1 min notably decreased weight loss (Ngure *et al.*, 2008). Mango fruit subjected to hot water at 55°C for 3 mins had lower decay for storage (Le *et al.*, 2010). Hot water treatment at 52°C in 5 mins was ideal for mitigation of anthracnose in mango fruits during 21 days of preservation (Patrick *et al.*, 2011). Hot water treatment at 55°C in 7 mins significantly prevented decay on tomato fruit (Manal *et al.*, 2019). Rapid hot water treatment (59-60ºC for 35 s) was superior to conventional hot water treatment (52- 55°C for 10 mins) in limiting anthracnose

Table 3. Effect of hot water treatment (°C/s) to decay index of pineapple during storage

Hot water (°C/s)	3	6	9	12	15
30/45	2.51±0.01^{a}	3.04±0.02^{a}	3.69±0.00^{a}	4.13±0.01^{a}	4.79±0.02^{a}
50/45	1.84±0.03^{bc}	1.99±0.00^{bc}	2.17±0.01^{bc}	2.34±0.03^{bc}	2.47±0.00^{bc}
52/40	1.52±0.02^{cd}	1.66±0.01^{cd}	1.82±0.02^{cd}	2.00±0.00^{cd}	2.11±0.03^{cd}
54/35	1.19±0.00^{de}	1.33±0.02^{de}	1.50±0.03^{de}	1.68±0.01^{de}	1.79±0.00^{de}
56/30	1.03±0.02^{e}	1.20±0.03^{e}	1.34±0.00^{e}	1.51±0.01^{e}	1.63±0.02^{e}
58/25	1.34±0.01^{d}	1.50±0.00^{d}	1.67±0.03^{d}	1.84±0.02^{d}	2.95±0.03^{d}
60/20	1.69±0.03^{c}	1.82±0.02^{c}	1.99±0.01^{c}	2.16±0.03^{c}	2.29±0.00^{c}
62/15	1.97±0.00^{b}	2.13±0.01^{b}	2.34±0.02^{b}	2.49±0.00^{b}	2.60±0.03^{b}

Values are presented as mean±SD, n = 3. Values with the same superscript within the same row are not significantly different (α = 5%).

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incidence (Pasilan *et al.*, 2020). Lenticel spots popularly occurred when fruits were dipped in hot water with excess duration or detergent (Chin *et al.*, 2010). Lenticel spots were also strongly correlated to gaseous exchange and transpiration (Rymbai *et al.* 2012).

The total soluble solid (TSS) contents in the control and treated samples are displayed in Table 4. The control at 30/45 (°C/s) showed the lowest TSS, while the sample treated at 56/30 (°C/s) preserved the highest TSS during 15 days of storage. TSS in all samples were found to have decreased during storage. Treated samples at 56/30 (°C/s) revealed a gradual decrease of TSS (24.35±0.02 to 23.01±0.01°Bx) meanwhile the control samples at 30/45 (°C/s) showed a sharp decrease (19.27±0.05 to 15.73±0.05°Bx). Exposure of pineapple to a higher temperature (>56°C) might facilitate stress response leading to an increase in respiration rate, decrease mRNA synthesis and increase in vulnerability to proteins and membranes of fruit (Paull and Chen, 2000).

Hot water at 46.5°C for 45 mins led to a higher total soluble solid of mango (Nyanjage *et al.*, 1998). Hot water dip at 53°C for 6 hrs had no significant impact on the total soluble solid of orange (Mustafa *et al.*, 2005). Dipping mango in hot water at 50°C for 5 mins was not significantly affected to total soluble solid content (Mansour *et al.*, 2006). The quality of kiwifruit was preserved better after hot water treatment (Femenia *et al.*, 2009). Bananas treated with hot water at 53°C for 9 mins resulted in higher TSS than the untreated ones (Amin and Hossain, 2013). Hot water treatment at 55°C in 7 mins maintained the total soluble solid content of tomato fruit (Manal *et al.*, 2019).

Ascorbic acid is one of the key organic acids in pineapple fruit. The ascorbic acid content in the control and treated samples were shown in Table 5. The control at 30/45 (°C/s) showed the lowest ascorbic acid content; while the sample treated at 56/30 (°C/s) preserved the highest ascorbic acid content during 15 days of storage. The ascorbic acid content in all samples decreased during storage. Treated samples at 56/30 (°C/s) revealed a gradual decrease of ascorbic acid content (18.59±0.01 to 17.79±0.02 mg/100 g) meanwhile the control samples at 30/45 (°C/s) showed a sharp decrease (13.74±0.01 to 10.45±0.02 mg/100 g). Hot water dip at 53°C for 6 hrs had no significant impact on the ascorbic acid of orange (Mustafa *et al.*, 2005). Dipping mango in hot water at 50°C for 5 mins was not significantly affected ascorbic contents (Mansour *et al.*, 2006). Mango fruit preliminarily treated with hot water, significantly maintained ascorbic acid content during 7 days storage at ambient condition (Pholoma *et al.*, 2020). Hot water treatment at 45°C resulted in a stabilized ascorbic acid content during 14 days of cool storage (Niazi *et al.*, 2021).

Table 4. Effect of hot water treatment (°C/s) to total soluble solid (°Bx) of pineapple during storage

Hot water (°C/s)	3	6	9	12	15
30/45	19.27±0.05^{e}	18.34±0.04^{e}	17.48±0.02^{e}	16.60±0.03^{e}	15.73±0.05^{e}
50/45	22.28±0.02^{cd}	21.90±0.05^{cd}	21.56±0.03^{cd}	21.17±0.01^{cd}	20.68±0.02^{cd}
52/40	23.13±0.01^{bc}	22.77±0.03^{bc}	22.38±0.01^{bc}	22.03±0.02^{bc}	21.70±0.04^{bc}
54/35	23.96±0.04^{ab}	23.62±0.01^{ab}	23.21±0.02^{ab}	22.91±0.04^{ab}	22.58±0.03^{ab}
56/30	24.35±0.02^{a}	24.06±0.03^{a}	23.64±0.01^{a}	23.32±0.02^{a}	23.01±0.01^{a}
58/25	23.52±0.01^{b}	23.20±0.02^{b}	22.79±0.03^{b}	22.50±0.00^{b}	22.17±0.04^{b}
60/20	22.70±0.03^{c}	22.31±0.00^{c}	21.99±0.04^{c}	21.59±0.01^{c}	21.26±0.02^{c}
62/15	21.91±0.02^{d}	21.46±0.04^{d}	21.13±0.01^{d}	20.72±0.04^{d}	20.25±0.05^{d}

Values are presented as mean±SD, n = 3. Values with the same superscript within the same row are not significantly different (α = 5%).

Table 4. Effect of hot water treatment (°C/s) to ascorbic acid content (mg/100 g) of pineapple during storage

Hot water (°C/s)	3	6	9	12	15
30/45	13.74±0.01^{e}	13.03±0.03^{e}	12.25±0.04^{e}	11.39±0.02^{e}	10.45±0.02^{e}
50/45	16.58±0.04^{cd}	16.32±0.02^{cd}	16.17±0.01^{cd}	16.04±0.03^{cd}	15.79±0.05^{cd}
52/40	17.39±0.03^{bc}	17.15±0.05^{bc}	16.95±0.02^{bc}	16.79±0.01^{bc}	16.63±0.03^{bc}
54/35	18.20±0.02^{ab}	18.01±0.04^{ab}	17.78±0.00^{ab}	17.60±0.02^{ab}	17.38±0.04^{ab}
56/30	18.59±0.01^{a}	18.40±0.02^{a}	18.22±0.03^{a}	18.01±0.00^{a}	17.79±0.02^{a}
58/25	17.78±0.04^{b}	17.57±0.03^{b}	17.34±0.01^{b}	17.18±0.03^{b}	17.01±0.01^{b}
60/20	17.00±0.02^{c}	16.73±0.01^{c}	16.56±0.02^{c}	16.42±0.02^{c}	16.24±0.00^{c}
62/15	16.21±0.01^{d}	15.89±0.02^{d}	15.73±0.04^{d}	15.52±0.05^{d}	15.31±0.03^{d}

Values are presented as mean±SD, n = 3. Values with the same superscript within the same row are not significantly different (α = 5%).

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4. Conclusion

Hot water treatment was highly valued as environmentally safe and non-chemically reactive. It effectively delayed fruit ripening and controlled its deterioration. Pineapple fruit treated by hot water at 56/30 (°C/s) compared to the control group had a lower weight loss and decay index but higher firmness, total soluble solids and ascorbic acid content. This pre-storage treatment maintained better fruit quality during storage at ambient conditions. It should be applied in large scale post-harvest as it is low cost and provides high efficiency. Findings in this research suggested that hot water treatment would be a promising technique to improve the product's marketability.

Conflict of interest

The author strongly confirms that this research was conducted with no conflict of interest.

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