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EFFECT OF ULTRASOUND TREATMENT COMBINED WITH SODIUM HYDROGEN SULFITE ON THE QUALITY OF POSTHARVEST LONGAN FRUIT

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Abstract. Longan is one of the fruits with a high economic value in Vietnam and is grown in both Northern and Southern provinces. However, the quality of longan fruits deteriorates quickly after harvest. The study aimed to combine ultrasound (US) treatment with a sodium hydrogen sulfite (SHS) solution as the wave transmission medium to reduce color changes and maintain the quality of longan fruit during storage at 25 ℃. Longan fruit was treated with US at a frequency of 192 kHz combined with SHS solutions at concentrations of 0.25% and 0.5% (w/v) for 1.5, 2.5, and 5.0 minutes. The results showed that the 0.5% SHS + US 1.5 min treatment effectively delayed color change of longan peel and reduced weight loss of the fruit, but did not affect the edible quality, including total titratable acidity and soluble solid content (°Brix), while maintaining vitamin C, total phenolic content, and antioxidant activity of longan fruit, compared to the control during 8 days of storage at 25 ℃. These results suggest that ultrasound treatment combined with sodium hydrogen sulfite can be potentially used for the preservation of longan fruit.

Keywords: antioxidant capacity, *Dimocarpus longan* L., longan fruit, sodium hydrogen sulfite, ultrasound.

1. Introduction

Longan (*Dimocarpus longan* Lour.) is a widely cultivated tropical fruit tree with significant commercial value, extensively consumed in countries such as China, Thailand, Vietnam, India, Pakistan, Australia, and South Africa [1]. However, ripe longan fruit, typically harvested during hot seasons, is highly susceptible to pericarp browning and microbial contamination, leading to a decline in postharvest quality, reduced antioxidant activity, and decreased consumer acceptance [1]. Consequently, effective postharvest

treatments are essential to prolong its storage life and maintain fruit quality.

Ultrasound (US) is a form of acoustic energy generated by high-frequency sound waves (above 16 kHz) that are imperceptible to the human ear [2]. As an emerging postharvest technology, ultrasound has been employed to preserve quality and extend the shelf life of fruits and vegetables. Compared to conventional postharvest treatments, ultrasound is recognized as a safer, non-toxic, and environmentally sustainable approach [3]. Previous studies have demonstrated that ultrasound treatment effectively mitigates color deterioration and preserves quality in various horticultural products, including longan [4], lychee [5], and fresh sweet potatoes [6]. However, inappropriate ultrasound frequencies and exposure durations may compromise the structural integrity of fruit tissues [7]. Therefore, integrating ultrasound with other complementary treatments that inhibit color changes in fruits and vegetables could optimize treatment efficiency, reduce processing time, and enhance the postharvest quality of longan fruit.

Sodium hydrogen sulfite (SHS), designated as food additive E222, is a white crystalline compound that is highly soluble in water and widely utilized in the food industry. It functions as a preservative and antioxidant, effectively preventing or delaying spoilage and enzymatic browning during food processing, storage, and distribution [8]. Additionally, SHS plays a crucial role in stabilizing product color, inhibiting discoloration, and enhancing the sensory properties of various food products [8]. Previous studies have demonstrated its efficacy in inhibiting enzymatic browning by suppressing the activity of polyphenol oxidases in longan [4], edible mushrooms (*Agaricus bisporus*) [9], and taro tuber's powder (*Colocasia esculenta* L. Schott) [10]. These findings suggest that SHS holds significant potential for integration with ultrasound technology to mitigate color changes and preserve the postharvest quality of fruits. However, the effects of ultrasound treatment combined with SHS on the quality attributes of postharvest longan fruit remain largely unexplored. Therefore, this study aims to investigate the influence of ultrasound-assisted SHS treatment on the postharvest quality of longan fruit, with a focus on key physicochemical parameters, including color stability, total titratable acidity, soluble solids content, vitamin C levels, phenolic compounds, and antioxidant activity.

2. Content

2.1. Materials and methods

2.1.1. Materials

**** Materials***

Golden flesh longan (*Dimocarpus longan* L.) was harvested at commercial maturity (120 - 125 days after fruit set) from Long Ho district, Vinh Long province. The harvested fruits were subsequently transported to the laboratory within 45 minutes under ambient conditions at 30 ± 2 °C.

**** Equipment***

The materials and equipment used in the study included test tubes, micropipettes, burettes, volumetric flasks, graduated cylinders, a Hunter Lab colorimeter (MH-C800

4500L, USA), a refractometer (Atago, Japan), a refrigerated centrifuge (Centrifuge 5430R, Germany), and a spectrophotometer (BioSpectrometer Basic D30, Germany).

2.1.2. Methods

**** Experiment 1. Assessment of the effects of US-SHS treatment on color change, weight loss, total titratable acidity, and total soluble solids content of longan fruit***

Longan fruits were selected for uniformity in color and shape, free from mechanical damage or visible signs of disease, and with individual weights ranging from 10.5 to 14.5 g. The fruits were thoroughly washed and rinsed under running water to remove any dirt and debris. A total of 385 longan fruits were randomly divided into 7 treatment groups. The samples were then placed into a washing tank connected to an ultrasonic wave generator system (600 mm × 380 mm × 350 mm; IDS 2415/SM; Crest Ultrasonic, USA), which had a power output of 180 W, along with a continuous circulating cold water system to maintain the tank's temperature at ambient levels during treatment. The ultrasonic generator was operated at a frequency of 192 kHz, with treatment durations of 1.5, 2.5, and 5.0 minutes, using SHS solutions at concentrations of 0.25% and 0.5% (w/v). A control group without ultrasonic treatment was also included. Following treatment, the samples were left to dry naturally at room temperature for 30 minutes and were stored at 25 °C in perforated polypropylene packaging (22 cm × 18 cm, with 16 holes, each 6 mm in diameter). Samples were taken at day 0 and every 2 days throughout an 8-day storage period for analysis of parameters including color difference (ΔE), weight loss, total titratable acidity, and soluble solids content. The experiment was conducted in a completely randomized design with three replications.

**** Experiment 2. Assessment of the effects of US-SHS treatment on vitamin C content, phenolic compounds, and antioxidant activity of longan fruit***

Experiment 2 was designed with two treatments: (i) no treatment (control) and (ii) longan fruit treated with the most effective combination of ultrasound and SHS solution. After the treatment, the samples were left to dry naturally for 30 minutes and stored at 25 °C in perforated polypropylene packaging. Samples were taken on day 0 and every 2 days during the 8-day storage period for analysis of vitamin C content, total phenolic content, and DPPH free radical scavenging activity. The experiment was conducted in a completely randomized design with three replications.

**** Analysis of longan fruit quality***

- Total color difference (ΔE):

The color change of longan fruit skin was determined according to Wen et al. (2020) [11], using a Hunter Lab colorimeter (MH-C800 4500L, USA). The values for L*, a*, and b* were recorded, and the color difference (ΔE) was calculated using the following formula:

$$(2.1): \Delta E = \sqrt{\left(L_0^* - L_t^*\right)^2 + \left(a_0^* - a_t^*\right)^2 + \left(b_0^* - b_t^*\right)^2} \quad (1)$$

Where L_0^*, a_0^*, and b_0^* refer to the values of the samples on day 0 (the initial sample) while L_t^*, a_t^*, and b_t^* represent the values of the samples on days 2, 4, 6, and 8 during the storage period.

- Soluble solid content (SSC) and total titratable acidity (TA):

The juice fruit was obtained by grinding the flesh using a mortar and pestle, then filtering the pulp through clean cloth, which was used for the analysis of SSC and TA. The SSC was determined using a refractometer (Atago, Japan). TA was determined by titrating 5 mL of fruit juice with 0.1 N NaOH and using phenolphthalein (1%) as an indicator. TA was expressed as a percentage of citric acid [12].

- Weight loss (%):

Weight loss was measured using an analytical balance with a readability of 0.01g, and the percentage of weight loss was calculated relative to the initial weight [13].

To prepare for the evaluation of vitamin C content, total phenolic content, and antioxidant capacity, the flesh of the longan fruit was ground into powder after being immersed in liquid nitrogen. Then, 0.2 g of the sample was mixed with 1.8 mL of cold methanol for the analysis of antioxidant activity and phenolic content or 5% cold metaphosphoric acid for the analysis of vitamin C content. The mixture was shaken thoroughly, vortexed for 1 minute, and centrifuged for 5 minutes at 10,000 rpm at 4 °C to obtain the crude extract.

- Vitamin C content:

The vitamin C content was determined following the method of Nguyen et al. (2021) [14], with slight modifications. The reaction mixture consisted of 0.4 mL of the extract, 0.6 mL of 0.02% diindophenol, 0.8 mL of 2% thiourea, and 0.6 mL of 2% dinitrophenylhydrazine, and was incubated at 50 °C for 1 hour. Subsequently, 1 mL of 85% sulfuric acid was added and incubated at room temperature (25 °C) for 30 minutes. The absorbance was measured spectrophotometrically at 540 nm, and the vitamin C content was calculated using a standard calibration curve under the same conditions.

- Total phenolics content:

The total phenolic content was quantified as described by Singleton et al. (1998) [15]. The reaction mixture consisted of 50 µL of the extract, 250 µL of Folin–Ciocalteu reagent, 750 µL of 7.5% sodium carbonate, and 2 mL of distilled water. The reaction mixture was vortexed and incubated at 40°C for 30 minutes. The absorbance was measured at a wavelength of 750 nm, and the results were calculated using a standard curve of gallic acid under the same conditions.

The antioxidant activity (% DPPH scavenging) was carried out according to Li et al. (2018) [16]. The reaction mixture contained 0.15 mL of the extract and 1.85 mL of 120 µM DPPH in methanol, which was then incubated at room temperature in the dark for 30 minutes. The absorbance was measured at a wavelength of 525 nm, and the results were calculated using the formula (2).

$$\%\text{DPPH inhibition} = \left(\frac{\text{Abs}_{\text{control}} - \text{Abs}_{\text{sample}}}{\text{Abs}_{\text{control}}}\right) \times 100 \quad (2)$$

**** Data analysis method***

The experimental data were analyzed using the Statgraphics Centurion XV statistical software. The data were expressed as the mean ± standard deviation (SD) of three replications. The Least Significant Difference (LSD) test was applied to compare the

treatment means at a 5% significance level for experiment 1, whereas the Pairwise t-test was utilized for experiment 2.

2.2. Results and discussions

2.2.1. Effect of US-SHS treatment on the color difference (ΔE) of postharvest longan fruit

The color of the longan peel is one of the important sensory indicators that affects the commercialization process of the fruit. The peel of the longan fruit turns brown rapidly within 2-3 days after harvest, primarily due to water loss and the activity of the enzyme polyphenol oxidase. This enzyme catalyzes the oxidation of phenolic compounds into quinones, which subsequently polymerize into brown pigments, thereby accelerating peel discoloration [4]. In this study, the color change of the longan peel was evaluated based on the color difference value ΔE. The greater the color deviation, the more significant the color change from the initial state. The analysis of data in Table 1 revealed that the ΔE value increased over storage time, and there were significant differences between the treatment groups on day 4 and day 6 ($p < 0.05$). On day 2 of evaluation, the ΔE values ranged from approximately 2 to 3; however, no significant differences were observed between the treatment groups (NT). On days 4 and 6, the ΔE values increased, ranging from 3 to 6 on day 4, and from 6 to 11 on day 6, showing significant differences between the treatment groups. It clearly showed that on day 6, the control group exhibited a ΔE value of 9.72 ± 2.03, representing a 4.2-fold increase relative to day 2 (2.31±1.29). Similarly, the 0.25% SHS + US for 2.5 min treatment reached a ΔE value of 11.07 ± 2.69, corresponding to a 3.4-fold increase from its day 2 value (3.25±1.64). Among all treatments, the 0.5% SHS + US for 1.5 min treatment showed the lowest ΔE on day 6 (6.58 ± 2.03), increasing only 2.9-fold compared with day 2 (2.29). After 8 days of storage, only the 0.5% SHS-US 1.5-minute treatment maintained its color, while all other samples had spoiled.

Table 1. Effect of US-SHS treatment on the color difference (ΔE) of postharvest longan fruit

Treatments	Color difference (ΔE)			
	Day 2	***Day 4***	***Day 6***	***Day 8***
Control	2.31^{a}±*1.29*	5.74^{ab}±*3.11*	9.72^{b}±*2.03*	-
0.5% SHS+US 1.5 min	2.29^{a}±0.91	3.77^{d}±2.37	6.58^{a}±2.03	7.36 ±3.31
0.5% SHS+US 2.5 min	3.22^{a}±1.14	5.42^{ab}±1.44	9.24^{b}±1.43	-
0.5% SHS+US 5.0 min	2.73^{a}±1.56	4.57^{abc}±1.29	9.25^{b}±2.66	-
0.25% SHS+US 1.5 min	3.18^{a}±1.88	4.86^{abc}±1.87	9.08^{b}±1.86	-
0.25% SHS+US 2.5 min	3.25^{a}±1.64	6.25^{a}±3.40	11.07^{b}±2.69	-
0.25% SHS+US 5.0 min	3.31^{a}±1.24	4.48^{cd}±1.64	-	-

Note: Different letters within the same column indicate significant differences at the 5% level based on the LSD test. Values represent the mean of three replicates and the standard deviation. "-" indicates samples that have spoiled.

This suggests that using high SHS concentrations (0.5%) or prolonged treatment times (5 minutes) affects the membrane permeability of the fruit peel. Prolonged immersion increases the permeability of the cell membrane, causing the peel structure to

become loosened and lose its resistance, leading to browning and creating conditions for microorganisms to invade and cause spoilage [17]. In this study, the results indicated that longan fruit treated with ultrasound in a 0.5% SHS solution for 1.5 minutes effectively limited browning and maintained the fruit's brightness. These findings align with previous studies showing that SHS effectively prevents browning by inhibiting the activity of browning enzymes in edible mushrooms (*Agaricus bisporus*) [9]. SHS has been proven as an antioxidant used in food preservation to slow down spoilage and prevent browning [8]. Other studies have also demonstrated that ultrasound treatment of lychee fruits is effective in reducing browning and maintaining postharvest quality [4], and ultrasound is also effective in reducing browning on peeled potatoes [18].

2.2.2 Effect of US-SHS treatment on the weight loss of postharvest longan fruit

Water loss is the primary factor contributing to weight loss during the storage of fresh fruit. The results presented in Table 3.2 demonstrate that weight loss across all treatments increased over time, with statistically significant differences observed among the treatments ($p < 0.05$). At the 2-day assessment, weight loss ranged from 3 - 4%. After 6 days of storage, the average weight loss increased to approximately 10 - 12%. By the end of the storage period (8 days), only the 0.5% SHS+US 1.5-minute treatment continued to exhibit measurable weight loss, while all other treatments had spoiled.

Table 2. Effect of US-SHS on the weight loss of postharvest longan fruit

Treatments	Weight loss (%)			
	Day 2	***Day 4***	***Day 6***	***Day 8***
Control	$3.86^{bc}\pm0.83$	$8.50^{ab}\pm1.11$	$12.94^{a}\pm1.09$	-
0.5% SHS+US 1.5 min	$3.28^{c}\pm0.87$	$6.92^{c}\pm1.24$	$10.64^{a}\pm1.41$	13.00±1.17
0.5% SHS+US 2.5 min	$4.82^{a}\pm0.09$	$8.99^{a}\pm0.74$	$11.67^{a}\pm1.48$	-
0.5% SHS+US 5.0 min	$3.79^{bc}\pm1.08$	$8.57^{ab}\pm1.17$	$11.11^{a}\pm2.62$	-
0.25% SHS+US 1.5 min	$4.29^{ab}\pm1.31$	$8.31^{ab}\pm1.14$	$12.53^{a}\pm2.06$	-
0.25% SHS+US 2.5 min	$4.04^{abc}\pm1.18$	$7.53^{bc}\pm1.03$	$10.83^{a}\pm0.85$	-
0.25% SHS+US 5.0 min	$3.88^{bc}\pm3.63$	$6.73^{c}\pm1.68$	-	-

Note: Different letters within the same column indicate significant differences at the 5% level based on the LSD test. Values represent the mean of three replicates and the standard deviation. "-" indicates samples that have spoiled

Weight loss in stored fruits and vegetables is primarily due to natural dehydration, driven by moisture loss and the degradation of dry matter during respiration [19]. In this study, treatment with ultrasound combined with SHS effectively reduced weight loss, with significant differences noted on days 2 and 4. This reduction can be attributed to the relationship between peel browning and weight loss: when browning occurs, the fruit peel structure is compromised, increasing the permeability of the cell membranes. As a result, during the latter stages of storage, the peel softens, leading to more rapid water evaporation and greater weight loss (control group). In contrast, longan treated with 0.5% SHS+US for 1.5 minutes exhibited the lowest ΔE (6.58), which contributed to minimizing weight loss. Damage or degradation of the cuticle or peel increases permeability, thereby accelerating dehydration, softening, and mass loss during postharvest storage [20]. Similarly, longan fruit weight loss increased progressively over time, reaching 23.98%

after 6 days at 10 °C and 50% relative humidity. A correlation was observed between pericarp water loss and pericarp browning index, suggesting that dehydration of the peel contributes directly to browning [21]

2.2.3. Effect of US-SHS on the total titratable of postharvest longan fruit

Overall, the total acid content of longan fruit did not change significantly throughout the storage period, and there was no difference between the treated and control samples (data not shown). The total acid content fluctuated on average between 0.03 and 0.07%. Among them, longan treated with 0.5% SHS+US for 1.5 minutes maintained a stable high level (0.05%) after 8 days of storage at 25 °C.

For fresh fruit preservation, post-harvest respiration continues to consume organic acids and dry matter to sustain life, which causes these values to decrease during storage [19]. However, longan fruit treated with ultrasound combined with SHS may reduce the utilization of total acid content by slowing down respiration, as evidenced by the reduction in weight loss shown in Table 2.

2.2.4. Effect of US-SHS on total soluble solid content of postharvest longan fruit

The soluble solid content (SSC) of longan fruit exhibited a slight increase throughout the storage period. At harvest (day 0), SSC ranged from 18 to 19 ^{o}Bx and gradually rose to approximately 20 - 21 ^{o}Bx after 6 to 8 days of storage. Although longan is a non-climacteric fruit, it continues to undergo respiration and metabolic transformations, leading to the conversion of soluble solids during storage [22]. However, no statistically significant differences were observed between the treated and control groups (data not shown). These results suggest that ultrasound treatment in an SHS solution medium does not adversely impact key edible quality attributes, such as total acid content and soluble solid content, in longan fruit. This finding aligns with previous studies on post-harvest longan preservation [23].

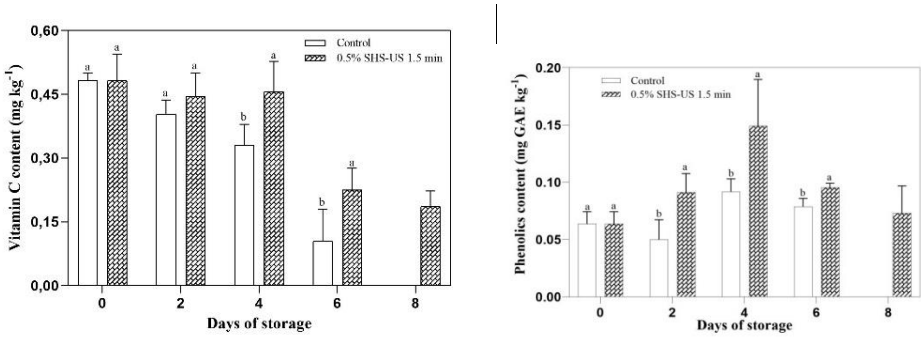
2.2.5. Effect of US-SHS on the quality attributes (vitamin C content, total phenolic content) of postharvest longan fruit

Based on the results of experiment 1, the SHS solution concentration of 0.5% w/v with treatment duration of 1.5 minutes was selected for use as the ultrasonic wave transmission medium in Experiment 2.

**** Vitamin C content***

Figure 1a illustrates the effects of US-SHS treatment on the vitamin C content of longan fruit during storage, highlighting differences between the treated and control samples at each storage time. At day 0 and day 2, vitamin C content ranged from approximately 0.4 to 0.5 mg kg^{-1}, with no significant difference between treatments. A significant difference between treatments was evident at day 4, when vitamin C content in the treated fruit remained around 0.45 mg kg^{-1}, whereas that of the control decreased to approximately 0.32 mg kg^{-1}. This difference persisted at day 6, with US-SHS-treated fruit exhibiting higher vitamin C levels (≈ 0.23 mg kg^{-1}) than the control (≈ 0.13 mg kg^{-1}). By day 8, vitamin C in the treated fruit retained approximately 0.18 mg kg^{-1}, while the control had spoiled. The application of ultrasound combined with SHS demonstrated the potential to retain vitamin C levels over the 8-day storage period. Postharvest respiration in fresh fruit involves the consumption of organic acids and total soluble solids to support

metabolic processes. Although no significant differences in total titratable acidity were observed between treatments, the 0.5% SHS+US treatment for 1.5 min showed a tendency to retard the depletion of organic acids, including vitamin C, and was associated with lower weight loss during storage. These results are consistent with previous studies on longan fruit, suggesting that ultrasound treatment may stimulate the synthesis of antioxidant compounds, thereby reducing vitamin C degradation in post-harvest longan fruit [4].



(a) ***(b)***

Figure 1. Effect of US-SHS on vitamin C (a) and phenolic content (b) of longan fruit

Note. Letters indicate significant differences between treatments. Pairwise t-tests were conducted at a 5% significance level. Values are expressed as mean ± standard deviation.

**** Total phenolic content***

The results presented in Figure 1b indicate that phenolic content increased during the initial stages of storage before gradually declining. A statistically significant difference was observed between the treated and control groups. On day 0, both the control and the 0.5% SHS-US treatment showed similar values (0.06 mg/kg). On day 2, the treated samples increased slightly to approximately 0.08 mg/kg, while the control remained near 0.06 mg/kg. The highest phenolic content was recorded in the 0.5% SHS+US for 1.5 min treatment on day 4, reaching about 0.15 mg/kg and around 0.10 mg/kg in the control. This trend can be attributed to the activation of phenylalanine ammonia-lyase (PAL) enzyme, which plays a crucial role in phenolic biosynthesis. The combination of ultrasound and SHS likely stimulated PAL activity, resulting in an initial increase in phenolic accumulation [6]. However, on day 6, phenolic levels decreased to roughly 0.09 mg/kg in the treated group and 0.08 mg/kg in the control. After 8 days of storage treatment with 0.5% SHS+US for 1.5 min showed a decline, with values close to 0.08 mg/kg, while the control fruit exhibited signs of deterioration. Potentially due to oxidative degradation and enzymatic browning, which suppresses phenolic biosynthesis [24]. Despite this reduction, the 0.5% SHS+US for 1.5 min treatment effectively maintained higher phenolic levels compared to the control group throughout storage. Previous studies have demonstrated that post-harvest physical treatments, such as ultraviolet-C (UVC) irradiation and ultrasound, can enhance bioactive compound accumulation and antioxidant enzyme activity in plant tissues, thereby strengthening natural defense mechanisms [4], [6]. Similarly, an increase in phenolic content has been reported in ultrasound-treated longan [4], mango [25], and peeled sweet potatoes [6]. Notably, in this study, both vitamin C and

phenolic content were significantly higher in longan fruit treated with the combined SHS-US method compared to the control group. This suggests a synergistic effect of SHS and ultrasound in preserving bioactive compounds, thereby improving the post-harvest quality of longan fruit.

2.2.6 DPPH radical scavenging activity

Antioxidant activity reflects the ability of cells to neutralize free radicals, thereby preventing oxidative damage. In this study, DPPH radical scavenging activity fluctuated throughout the storage period (Figure 2). On day 0, both the control and the 0.5% SHS+US for 1.5 min treatment exhibited similar antioxidant levels of approximately 22 - 23%. By day 2, the treated fruit showed a slight reduction to about 20%, while the control did not change. On day 4, the 0.5% SHS+US for 1.5 min treatment reached its peak value of about 34%, significantly higher than the control (≈ 27%). Afterward, antioxidant activity declined, dropping to roughly 25% on day 6 and 22% on day 8 in the treated fruit. Despite this decrease, the SHS+US treatment consistently maintained higher DPPH scavenging activity than the control throughout storage.

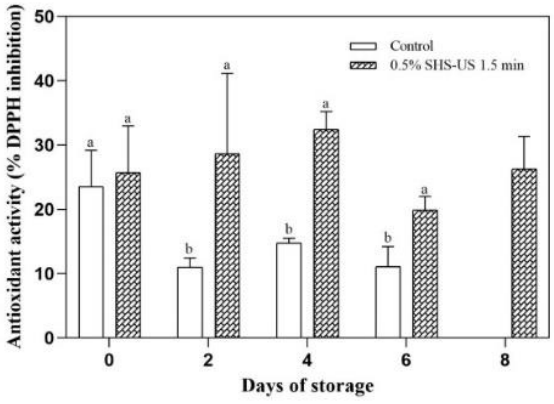


Figure 2. Effects of US-SHS on the DPPH radical of postharvest longan fruit

Note. Letters indicate significant differences between treatments. Pairwise t-tests were conducted at a 5% significance level. Values are expressed as mean ± standard deviation.

These findings are consistent with previous studies, such as peeled sweet potatoes treated with ultrasound, which demonstrated an enhanced antioxidant capacity [6]. The decline in DPPH observed in the control correlates with the reduction in phenolic content and vitamin C levels. During postharvest storage, respiratory metabolism contributes to the degradation of nutrients such as organic acids, phenolic compounds, and vitamin C. In this study, differences in phenolic content and vitamin C levels between the control and fruit treated with 0.5% SHS+US for 1.5 min were observed at specific storage times. The treated fruit generally exhibited higher phenolic content and vitamin C levels than the control, particularly at the later days of storage. These results suggest that the combined treatment of 0.5% SHS-US effectively mitigates oxidative stress and nutrient depletion in longan fruit, preserving bioactive compounds more effectively than untreated samples. Similar findings have been reported in peeled potatoes [18] and sweet potatoes [6] treated with ultrasound, further supporting the efficacy of this approach in maintaining antioxidants during storage.

3. Conclusions

Golden-flesh longan treated with a combination of US for 1.5 minutes and 0.5% SHS solution as the transmission medium effectively preserved post-harvest fruit quality. This combined treatment maintained the peel color, reduced weight loss, and did not negatively impact the edible quality (total titratable acidity and soluble solid content) of longan fruit. Additionally, it helped retain vitamin C, phenolic compounds, and antioxidant activity in longan fruit after 8 days of storage at 25 °C. These findings highlight the potential of US-SHS treatment as a promising post-harvest technology for reducing losses in fruits and vegetables while preserving their nutritional and sensory qualities.

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