COMBINATION OF HEAT TREATMENT, CHITOSAN COATING AND MODIFIED ATMOSPHERE PACKAGING TO IMPROVE POST-HARVEST QUALITY OF DA BO LONGAN FRUIT

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ABSTRACT

This study investigated the effects of the combination of hot water treatment (HWT), chitosan coating, and modified atmosphere packaging (MAP) on the quality and storage time of Da Bo longan fruits. The results indicated that longan fruits treated by HWT at 52 ºC for 30 seconds before the coating of chitosan 0.2% at pH 3.3 for 2 mins and stored in MAP (Lifespan) inhibited post-harvest pathogens, delayed the changes in color, reduced the pericarp browning and extended the shelf life of longan fruits during storage at 5 ± 1 °C. The shelf life of treated longan fruits was up to 35 days when stored at 5 ± 1 °C, relative humidity (RH) of 85-90%.

Keywords: Coating chitosan, hot water treatment, longan fruit, MAP, post-harvest quality.

1. INTRODUCTION

Longan is a tropical plant species that produces edible fruit, native to Southern Asia. The seed is small, enamel-like, lacquered black, round and hard. The fruit of the longan is similar to that of the lychee but less aromatic in taste. The fully ripened, freshly harvested fruit has a bark-like shell, thin, and firm, making the fruit easy to peel by squeezing the pulp out. The tenderness of the shell varies due to either premature harvest, variety, weather conditions, transport or storage conditions.

Post-harvest longan fruit shelf-life is usually short due to pericarp browning and fungal diseases [1]. Modified atmosphere packaging (MAP) for longan fruits storage at low temperature was both quality maintenance and increase in maneuverability on the market. However, MAP packaging was not effective for pathogens [2]. To address this disadvantage, alternative methods have been developed to prolong the storage time and inhibit the development of pathogens at 5 ± 1 °C, relative humidity (RH) of 85-90% [3]. Sulfur dioxide (SO_2) fumigation has been used on the longan fruit shells because SO_2 is a reducing agent that can prevent longan fruits from turning brown by reducing polyphenol oxidase (PPO) activity [4]. However, there have been many reports on the negative effects of used sulfur dioxide's toxic residuals on human beings, particularly for asthmatics and sensitive individuals.

Alternatively, chitosan coating was reported to improve the color of Da Bo longan fruits skin (pH 3.3) [5, 6]. The preservation by MAP combined with low storage temperature is an effective method to ensure the quality and increase the usability of fresh vegetables. In which, the preservation of fresh longan with only MAP bags has been studied but not effective in long-term control of pathogens after harvest [2]. However, the use of strong fungicides and chemical sprays in combination with MAP bags is a treatment method that has been used to control pathogens on fresh longan, but residue and unsafe issues should be addressed. The irradiation method with low doses is also an option to control pathogens and it is a mandatory requirement when exporting strict markets. However, the irradiation with low doses needs to be combined with other treatment methods to control the rate of browning skin and maintain the color of longan fruits [3]. Therefore, hot water treatment has become a viable, safe option because it not only controls the disease but also contributes to the slowing browning of the longan shell [7]. Besides, the characteristic of longan fruit skin is less light. Thus, the controlling fungal pathogens and browning skin should be done in time with the improvement of skin color; Chitosan coating in a pH 3.3 was better longan skin color chitosan coating (pH 3.3) on delaying pericarp browning of longan fruit. However, pathogens have not been effectively controlled, so it only lasts up to 27 days of preservation [6]. Especially, the multi-combined method has been studied widely [8]. However, the combination of short-term high-temperature hot water with chitosan dissolved in acid pH and storage in MAP bags has not yet been published in case of Da Bo longan fruit. Therefore, this study was to develop a safe, effective and low-cost method for storage of Da Bo longan fruit by the combination of hot water treatment, chitosan coating, and MAP packaging. This method becomes a good choice to control fungal diseases and skin browning of longan fruits. This study investigated the effects of a combination of hot water treatment, chitosan coating, and MAP packaging on quality and shelf life of fresh longan fruits at 5 ± 1 °C storage, relative humidity (RH) of 85-90%.

2. MATERIALS AND METHODS

2.1. Materials

Da Bo longan fruits with the same color skin ($L^* > 50$, $b^* > 31.50$), average weight of 10.07 ± 0.95 g and diameter in a range from 1.5 to 2 cm were harvested in Tien Giang province, Vietnam. All blemished, damaged or diseased fruits were carefully discarded.

MAP bags: PP (Polypropylene) (0.05 mm), Zoe (0.02 mm), PE (Polyetylen) (0.03 mm), lifespan 201 (0.03 mm) were bought from Plant and Food Research, New Zealand. The amount of penetrated oxygen and discharged carbon dioxide were 1271×10^{-13} mol.s^{-1}.m^{-2}.Pa^{-1} and 5330×10^{-13} mol.s^{-1}.m^{-2}.Pa^{-1}, respectively.

Chemicals used in the study included: sodium hydroxide, phenolphthalein, acetic acid, citric acid, raw chitosan powder (deacetyl degree of 85%), and sodium hypochlorite solution from Merk, Germany.

All experiments were conducted in storage chiller equipment at 5 ± 1 °C and 85-90% RH.

2.2. Methods

The rate of browning of Da Bo longan fruit's pericarp was visually assessed by using a browning scale as follows:

$$\text{Browning index} = \sum_{i=0}^{5} x.i(/\text{n (point)} \quad (1)$$

where, i: points value corresponding to browning scale; x: number of pericarp browning fruits (related to i); n: total browning fruits. Fruits having a browning index > 3.0 were unacceptable.

The percentage of diseased fruits was visually determined by deducting a total of tested fruits to fungal and rotting fruits.

The weight loss percentage of longan fruit was determined by Equation (2):

$$L (\%) = (m_i - m_f) \times 100/m_i \quad (2)$$

where m_i is the initial weight of longan fruit (g); m_f is the weight of longan fruit after storage (g).

Total soluble solids (TSS) content was determined by blending the pulp of longan fruit and measurement by a digital refractometer at 20 °C.

The color of the fruit pericarp was measured using a colorimeter according to the CIE (L*a*b*) (Commission International d'Eclairage). The parameter a* is positive values for reddish colors and negative values for the greenish ones, whereas b* is positive values for yellowish colors and negative values for the bluish ones. L* is an approximate measurement of luminosity, which is the property according to each color, cosidered each color can be considered as equivalent to a member of the greyscale, between black and white [9] and The color of the fruit is measured with a color meter KONICA MINOLTA - CR 400, Japan.

The content of CO_2 and O_2 in packaging during storage time was measured by Dansensor equipment (CheckMate 3, Denmark). Prior to the measure, silicon rubber septum was pasted on the sealed packaging surface, needles from Dansensor equipment would take air in the packaging through this patch to determine the content of CO_2 and O_2.

Chitosan films were prepared by dissolving 0.2%, 0.5% and 1% (w/v) of chitosan in a 0.5% (v/v) acetic acid aqueous solution [10, 11] containing 0.1% (w/v) Tween - 80 on the hot plate magnetic stirrer [12]. Acetic acid aqueous solution and Tween 80 help to improve chitosan dissolution and the humidity of the chitosan films. The pH of the mixture was adjusted to pH 3.3 by citric acid 3N and NaOH 1N. Chitosan mixture was homogenized for 90 s and then longan was immersed in the chitosan solution for 2 min and air-dried at room temperature for 30 min. A sample immersed in water without chitosan (pH 3.3) was used as control.

All experiments were triplicated. Data were analyzed using analysis of variance (ANOVA) and pairwise comparison tests were applied by means of the SAS statistical software version 9.0. The least significant difference (LSD) was calculated to compare significant effects at 5% level, and only significant differences were discussed unless stated otherwise.

3. RESULTS AND DISCUSSION

3.1. Effects of different MAP to storage of Da Bo longan fruits

The changes in the concentration of O_2 and CO_2 during storage in different MAP bags (Lifespan, Zoe, PP, and PE) were shown in Figure 1.

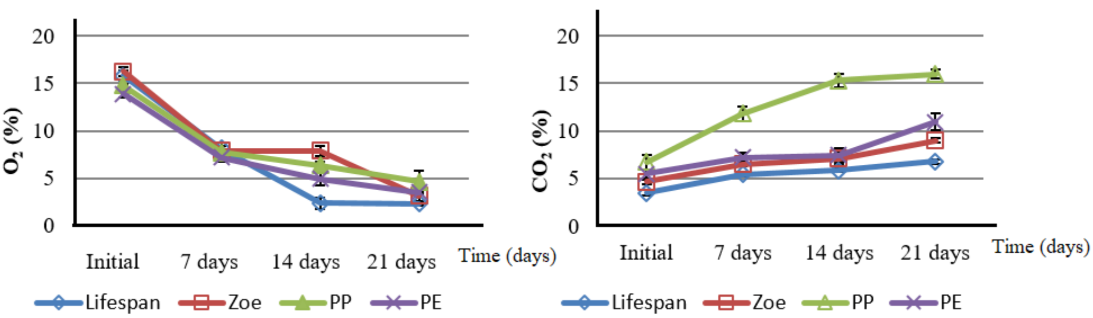

Figure 1. Changes in the concentration of O_2 and CO_2 during storage in different MAP bags

The given data depicted that the concentration of O_2 in Lifespan package was low (2.39%) in the first 14 days and this trend decreased to 2.31% until day 21st. In Lifespan bag, lower level of oxygen reduced the respiration rate and CO_2 production in 21 days while Zoe, PE, and PP bags still maintained the respiration rate and the amount of CO_2 increased.

Longan fruit skin color: Lifespan and Zoe maintained low O_2 concentration and reduced PPO activity and browning. Therefore, the browning rate slowed down and good yellow pigment was maintained until day 21st (Table 1). Whereas, the browning rate in PP, PE bags quickly occurred after 7 days in storage and b* values were significantly decreased.

Table 1. The effects of MAP bags on skin color (b^*)

Bags	b*			
	Storage time			
	Initial	7 days	14 days	21 days
Lifespan	32.44 ± 0.70^{b}	37.22 ± 1.08^{a}	34.82 ± 1.30^{a}	33.41 ± 0.16^{a}
Zoe	33.89 ± 0.15^{ab}	36.02 ± 1.45^{a}	34.22 ± 1.52^{a}	32.24 ± 1.38^{ab}
PP	32.71 ± 0.34^{ab}	35.11 ± 0.73^{b}	30.91 ± 0.41^{c}	30.47 ± 0.12^{c}
PE	33.54 ± 0.32^{ab}	35.02 ± 1.01^{b}	33.02 ± 1.14^{b}	31.63 ± 0.67^{bc}
Control	33.58 ± 0.49^{ab}	29.56 ± 1.02^{c}	25.76 ± 0.58^{d}	23.83 ± 1.20^{d}
$LSD_{0.05}$	1.32	1.19	0.87	1.48
CV (%)	2.00	2.59	2.09	3.71

Note: Means with the same letters (in each storage time) are not significantly different at $P < 0.05$

Longan fruit quality: The percentage of TSS was a valuable parameter to evaluate fresh longan fruits [13]. The MAP bags storage at low temperature remarkably slowed down the physical, biochemical changes of longan fruits. Table 2 indicates that %TSS was highest in Lifespan bag. This means that the respiration rate in Lifespan was lower than that of other bags and control. Although %TSS of Zoe and Lifespan showed no difference, the values of b* of longan skin when stored in Lifespan was higher than in Zoe package after 21 days of storage. The color of longan skin was the first criterion for customers to make a decision to buy items. Thus, Lifespan was selected because it protected the bright color of longan skin.

Table 2. The effects of MAP bags on %TSS

Bags	Total soluble solid (%TSS)			
	Storage time			
	Initial	7 days	14 days	21 days
Lifespan	21.08 ± 0.09^{a}	20.98 ± 0.20^{a}	20.80 ± 0.20^{a}	20.34 ± 0.19^{a}
Zoe	21.04 ± 0.26^{a}	20.72 ± 0.19^{a}	20.46 ± 0.06^{ab}	20.16 ± 0.03^{a}
PP	21.02 ± 0.03^{a}	20.66 ± 0.13^{a}	20.20 ± 0.38^{b}	19.58 ± 0.20^{c}
PE	21.16 ± 0.26^{a}	20.78 ± 0.03^{a}	20.50 ± 0.05^{ab}	19.90 ± 0.17^{b}
Control	21.02 ± 0.24^{a}	19.98 ± 0.35^{b}	19.46 ± 0.01^{c}	19.08 ± 0.06^{d}
$LSD_{0.05}$	0.33	0.35	0.55	0.24
CV (%)	1.18	1.28	2.05	0.93

Note: Means with the same letters (in each storage time) are not significantly different at $P < 0.05$

3.2. The combination of hot water treatment and MAP bags

The combination effect of hot water treatment and MAP bags on the storage of longan fruits at different temperatures on the rate of fungal diseased fruits over total tested fruits was presented in Table 3.

Table 3. Effects of the combination of hot water treatment and MAP bags on the rate of fungal diseased fruits and total of tested fruits after different storage time

Treatment time	Temperature			
	Control	48 °C	52 °C	56 °C
Fungal diseased fruits/ total tested fruits				
After 14 days				
15 seconds	5.00 ± 0.00	5.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
30 seconds	6.67 ± 3.18	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
60 seconds	6.67 ± 3.18	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Mean	6.11^{a}	1.67^{b}	0.00^{c}	0.00^{c}
After 21 days				
15 seconds	13.33 ± 4.06	5.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
30 seconds	13.33 ± 4.06	5.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
60 seconds	10.00 ± 0.00	5.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Mean	12.22^{a}	5.00^{b}	0.00^{c}	0.00^{c}
After 28 days				
15 seconds	25.00 ± 0.00	20.00 ± 1.76	8.33 ± 2.23	0.00 ± 0.00
30 seconds	26.67 ± 1.85	16.67 ± 2.18	0.00 ± 0.00	0.00 ± 0.00
60 seconds	23.33 ± 1.85	10.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Mean	25.00^{a}	15.56^{b}	2.78^{c}	0.00^{d}

Note: Means with the same letters (in each storage time) are not significantly different at P < 0.05

The rate of fungal diseased fruits treated at high temperature was lower than that of low treated temperature. After 28 storage days in treatments at 52 °C and 56 °C for 30, 60 seconds, the longan fruits were maintained in good condition. The significant difference of experiments was observed when compared to control (only use Lifespan bag). Moreover, hot water treatment time also showed the effectiveness in the prevention of fungi grown on fruits. The treatment times of 30 seconds and 60 seconds were more effective against diseases than that of 15 seconds (Table 3). This results can be explained that the treatment by hot water at 52 °C and 56 °C cleaned the impurities and fungus on the longan skins [14], leading to prevent the longan fruits from fungal diseases. The changes in longan fruits skin color (b^*) at various temperature levels and hot water treatment time periods at 5 ± 1 °C, relative humidity (RH) of 85-90% were given in Table 4.

Table 4. The effects of hot water treatment at 52 and 56°C to skin color (b^*) at different treatment time

Treatment time	Temperature			
	Control	52 °C	Control	56 °C
	Initial			
15 seconds	32.60 ± 1.13	32.98 ± 0.57	32.39 ± 0.61	33.53 ± 0.69
30 seconds	32.46 ± 0.61	33.04 ± 0.52	32.46 ± 0.34	32.21 ± 0.87
60 seconds	32.27 ± 0.99	33.07 ± 0.58	33.13 ± 0.54	32.32 ± 1.00
Mean	32.44^{b}	33.03^{a}	32.66^{ab}	32.69^{ab}

	After 14 days			
15 seconds	32.79 ± 1.91	34.40 ± 0.81	36.50 ± 4.51	32.85 ± 2.10
30 seconds	33.91 ± 1.25	33.51 ± 0.32	35.94 ± 0.73	31.18 ± 1.89
60 seconds	34.32 ± 0.08	32.90 ± 1.05	35.55 ± 2.59	30.79 ± 2.32
Mean	33.74[b]	33.27[b]	36.00[a]	31.60[c]
	After 21 days			
15 seconds	32.46 ± 1.36	34.86 ± 0.81	36.22 ± 1.21	31.79 ± 1.15
30 seconds	33.13 ± 1.59	34.71 ± 0.59	35.63 ± 0.68	30.72 ± 0.86
60 seconds	32.89 ± 0.36	32.67 ± 0.97	35.13 ± 1.72	30.95 ± 0.63
Mean	32.83[c]	34.08[b]	35.66[a]	31.15[d]
	After 28 days			
15 seconds	31.93 ± 0.04	32.58 ± 1.13	32.40 ± 1.33	30.37 ± 0.64
30 seconds	31.77 ± 1.09	32.23 ± 0.72	32.54 ± 1.43	29.83 ± 1.34
60 seconds	31.65 ± 1.95	32.16 ± 1.69	33.19 ± 0.67	25.85 ± 0.49
Mean	31.79[a]	32.31[a]	32.71[a]	28.68[b]

Note: Means with the same letters (in each treatment time) are not significantly different at P < 0.05

Table 4 showed that the longan fruits treated with hot water at 52 °C were the most appropriate method to keep the bright color of longan skin during 21 storage days. The hot water treatment at 56 °C caused longan fruits damage by heat and increased the browning rate, which reduced storage time. As a result, the heat treatment condition of the fruit at 52 °C in 30 seconds was optimized for further experiments.

3.3. The effects chitosan coating on skin color

The effects of chitosan coating conditions on the rate of browning skin were shown in Figure 2.

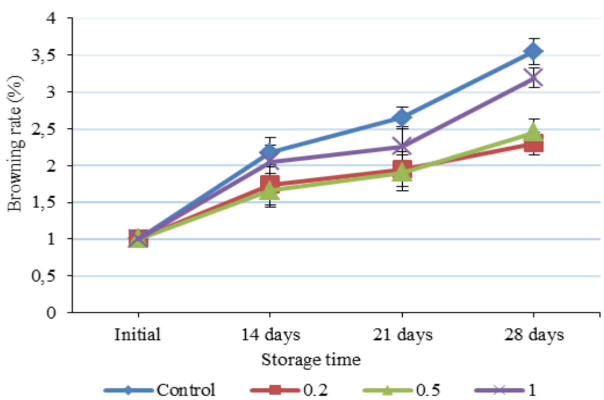

Figure 2. The effects of chitosan concentrations in the coating on the rate of browning skin

Browning rate was signigicantly lower at 0.2% and 0.5% chitosan coating in 28 days storage compared to 1% chitosan. However, there was no difference between 0.2% and 0.5% chitosan coating on the quality of longan fruits.

The changes in longan fruits skin color (b^*) at various chitosan concentrations and treatment times at 5 ± 1 °C, relative humidity (RH) of 85-90% are given in Table 5.

Table 5. The effects of chitosan coating (0.2%, 0.5%) on the color (b^*) of longan skin

Concentration (%)	b^*			
	Storage time (days)			
	Initial	14 days	21 days	28 days
Control	33.79 ± 1.05[b]	31.81 ± 1.35[b]	32.84 ± 1.39[b]	28.98 ± 0.86[b]
0.2	36.84 ± 1.08[a]	36.29 ± 1.08[a]	36.21 ± 2.58[a]	35.20 ± 0.24[a]
0.5	36.91 ± 1.00[a]	35.95 ± 1.00[a]	35.53 ± 0.26[a]	35.14 ± 1.38[a]
1	37.20 ± 1.16[a]	33.90 ± 2.16[b]	32.98 ± 0.96[b]	29.02 ±1.24[b]
$LSD_{0.05}$	1.25	0.81	0.68	0.92
CV (%)	2.24	1.72	1.48	2.13

Note: Means with the same letters (in each storage time) are not significantly different at $P < 0.05$

Figure 2 and Table 5 indicated that the yellow pigment of pericarp increased after treatment with chitosan solution (pH 3.3) combined with storage in Lifespan bags in comparison to control samples during 28 days in storage. Chitosan coating at 1% was not a better protection than chitosan coating at 0.2% and 0.5%. Generally, attacking of fungi or bacteria may be an important factor causing the discoloration of fruits. Thus, inhibiting decay would be beneficial in delaying browning of the products. In this study, chitosan formed a semipermeable film that regulated gas exchange and reduced transpiration rate and fruit ripening [15]. These results were similar to the report that chitosan coating suppressed the decline in sensory quality and extended storage life of the table grape [16].

There was no clear difference in the rate of browning skin and color of longan skin which coated by 0.2% and 0.5% of chitosan. Thus, 0.2% chitosan coating at pH 3.3 was selected for further study. The combination of a chitosan film and a preservation MAP bag were used. The thick chitosan film (1%) resulted in an anaerobic environment (2% oxygen and 9.75% CO_2) after 28 days. In addition, the preliminary survey was conducted with the rate of 1%, 1.2%, and 1.5%, the results showed that a high concentration of chitosan resulted in high viscosity, which was not effective in color maintenance and fungal control.

3.4. The effects of the combination of hot water treatment (HWT) and chitosan coating (HWT-chitosan) on longan fruits

The combination between hot water treatment (HWT) at 52 ºC and 0.2% of chitosan coating at pH 3.3 (HWT-chitosan) was conducted to investigate the effect of this mixture on quality and storage time on longan fruits. The results were presented in Figure 3, 4, 5, and 6. Figure 3 indicated the rate of fungal disease fruits.

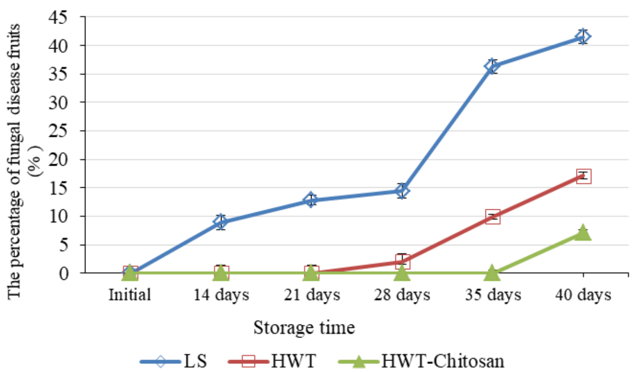

Figure 3. The effects of HWT at 52 °C, and chitosan coating 0.2% (HWT-chitosan) at pH 3.3 on the rate of fungal disease fruits

Figure 3 showed that HWT-chitosan treatment could control fungal pathogen from 28 to 35 days. However, after 40 days of storage, the number of fungal diseased longan fruits remarkably increased. The results also indicated that the combination of hot water treatment (HWT) with chitosan coating was the best treatment method to inhibit fungal pathogen during first 35 days compared with hot water treatment only. This was due to the combination of hot water treatment and chitosan coating avoided hurting of fruits by heating and saved energy. Moreover, at high temperature in a long time or high chitosan concentration could control fungal pathogen [5, 17].

The effects of HWT at 52 °C and chitosan coating 0.2% on the browning rate of fruits were depicted in Figure 4.

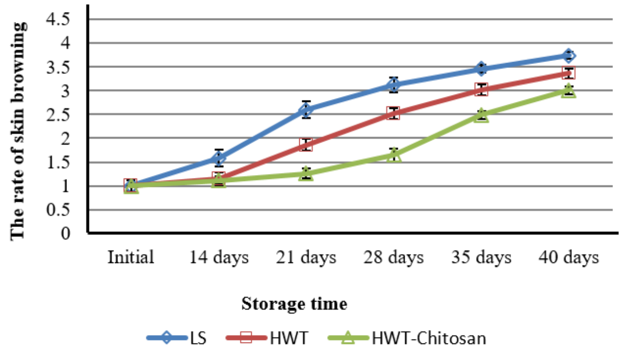

Figure 4. The effects of HWT at 52 °C and 0.2% of chitosan coating (HWT-chitosan) at pH 3.3 on the rate of browning skin

Figure 4 showed that after 35 storage days, HWT-chitosan treatment led to browning rate 2.49 which was commercial acceptance. However, the fruits treated with HWT only and control samples showed a browning rate over 3.0 meaning unfavorable in the market [6]. Therefore, hot water treatment at 52 °C in 30 seconds could reduce tense of epidermis on the fruit skin. Otherwise, chitosan solution dipped-fruits created acid pH (the mixture was adjusted to pH 3.3 by citric acid 3N) on the surface of longan fruits as well as heat impaction delayed the activity of polyphenol oxidase (PPO) which was associated with the increased resistance against infection by pathogens' causal organisms [18]. HWT exhibited effects on the epidermis, increasing evapotranspiration and affecting storage time. Hot water treatment also killed fungal pathogens. However, high water temperature treatment would give the opposite effects: the loss of dry matter because high temperature resulted in epidermis damage of shell, increasing evaporation and increasing mass loss. This method treatment controlled fungal diseases compared to original longan fruits because natural moisture increases softshell which affects preservation as well as increases fungal diseases.

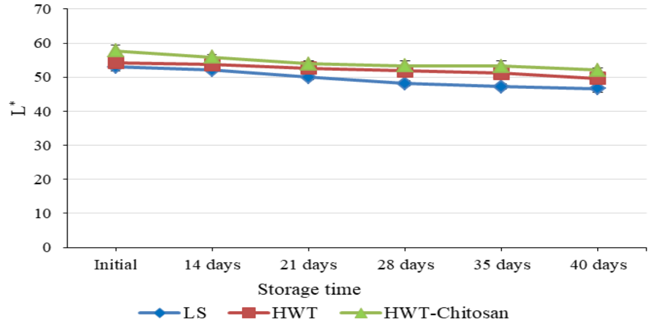

Figure 5. The effects of HWT at 52 °C and 0.2% of chitosan coating (HWT-chitosan) at pH 3.3 on L^* value

All longan fruits were treated by hot water at 52 °C and 0.2% of chitosan at pH 3.3 had significant higher yellow pigment (b^*) than that of control and non-treated hot water fruits. Chitosan coating at pH 3.3 reduced respiration rate, browning reaction, and identical color during storage [7].

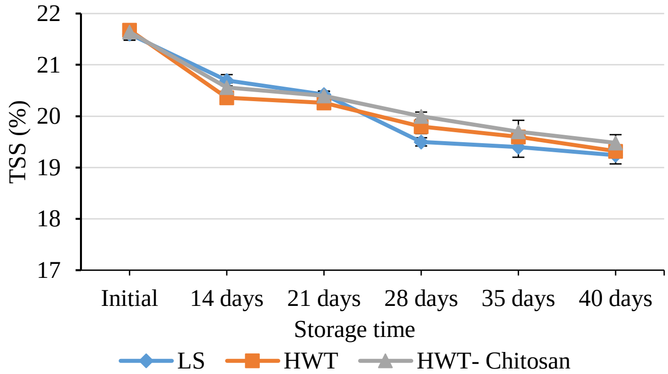

Figure 6. The effects of HWT at 52 ºC and 0.2% of chitosan coating (HWT-chitosan) on %TSS

The percentage of TSS% of longan fruits after treatment with hot water and chitosan reduced gradually over time. However, the soluble solids decreased more quickly in non-treated hot water samples. The results were also consistent with the report of Djioua *et al* (2010), Shiri *et al* (2013) [19, 20]. They claimed that the combination of hot water treatment and chitosan maintained %TSS during storage. The results showed that at the day 35th, longan fruits still maintained the characteristic aroma and flavor. By the day 40th, a part of the surface showed fungal pathogens and the characteristic aroma and sweet taste were affected. Besides total acid, TSS% was also a criterion to assess the good eating quality of the pulp. After 35 days, TSS% tended to reduce due to the respiratory process of longan fruits [21]. After 40 days at 5 ± 1 ºC, relative humidity (RH): 85-90%, the product quality decreased noticeably and that was not commercially acceptable.

4. CONCLUSIONS

Lifespan was a suitable bag to improve the quality of Da Bo longan fruits in term of skin color, TSS (%) after 14 storage days. Fruits were treated with water at 52 °C for 30 seconds showed delayed fungal disease and pericarp browning during 28 days. Chitosan coating at 0.2%, pH of 3.3 maintained good skin color for 21 days. A combination of hot water at 52 °C with 0.2% of chitosan coating at pH 3.3 and storage of Da Bo longan fruits in lifespan bag improved the antimicrobial effect to 35 days of storage. The fruits were preserved at 5 ± 1 °C, 85-90% RH. For practical applications, it is recommended to combine conveyor-type equipment to increase automation, identify the fungal pathogen and determine the enzyme activity that causes browning for better control. After 35 days, the fungal pathogen has developed, and therefore, reducing the quality of fruit flesh and dragging the color, TSS% has decreased significantly.

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TÓM TẮT

NGHIÊN CỨU BẢO QUẢN NHÃN TIÊU DA BÒ BẰNG PHƯƠNG PHÁP KẾT HỢP XỬ LÝ NƯỚC NÓNG VỚI PHỦ MÀNG CHITOSAN VÀ BAO BÌ BIẾN ĐỔI KHÍ QUYỂN

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Mục tiêu của nghiên cứu này là kết hợp xử lý nước nóng, phủ chitosan và bao bì khí quyển điều chỉnh để ức chế mầm bệnh sau thu hoạch, giảm sự thay đổi màu sắc, giảm màu nâu và kéo dài thời gian bảo quản của quả nhãn trong quá trình bảo quản ở mức 5 ± 1 °C. Kết quả cho thấy các điều kiện phù hợp để giữ chất lượng sau thu hoạch tốt là xử lý nhiệt ở 52 °C trong 30 giây trước khi phủ chitosan 0,2% (w/v) (pH 3,3) trong 2 phút cộng với đóng gói trong túi Lifespan. Thời hạn sử dụng lên tới 35 ngày khi được bảo quản ở 5 ± 1 °C, RH 85-90%.

Từ khóa: Phủ chitosan, xử lý nước nóng, nhãn, MAP, chất lượng sau thu hoạch.