Effect of hydrogen sulfide(H₂S) fumigation on quality of passion fruit (*Passiflora edulis* Sims)

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Abstract. In order to investigate the effects of H₂S on the quality of cold-storage passion fruit, fresh harvested fruits were treated with different concentrations of H₂S(0 mmol/L, 1 mmol/L, 2 mmol/L, 3 mmol/L), packaged with BOPP plastic wrap and placed into 5±1°C for 35 days. Samples were randomly selected and at 7-days interval during cold storage, compared the preservation effect of different concentrations of H₂S. The results indicated that the fruits with 2 mmol/L H₂S treatment have better chroma and lower weight loss rate, and soluble solid content, titratable acidity, vitamin C, sugar were preserved at higher level than that of control fruits during storage time. These results showed that 2 mmol/L H₂S treatment could maintain the quality of passion fruit during cold storage.

1 INTRODUCTION

Passion fruit (*Passiflora edulis* Sims) is grassy vine of the passifloraceae, the scientific name is *passiflora*, also known as egg fruit or Brazil fruit. It is an important raw material for juice and wine as its rich aroma and various nutrients^[1,2]. Passion fruit is a kind of tropical fruit originated from Brazil, it has strong respiration and fast ethylene response while at a high temperature in the mature season, seriously water lose during storage, prone to shriveling, peel color darkening, rot, fermentation to bad odor, etc^[3,4]. Therefore, it is all-important to study the preservation of post-harvested passion fruit to maintain its commodity and prolong its shelf life.

Hydrogen sulfide (H₂S), a colorless poisonous gas with an odor of rotten egg^[5-7], which is another signal molecule after nitric oxide(NO) and carbon monoxide(CO)^[8-10]. H₂S in plant is mainly produced by the degradation of cysteine catalyzing by D-/L cysteine desulphhydrase or the reduction of SO₃²⁻ by sulfite reductase^[11,12]. Recently a large number of studies have shown that H₂S acts as a second messenger participating in many plant physiological processes: regulate stomatal movement, participate in photosynthesis, respond to drought or low temperature stress, delay the senescence of postharvested fruits and vegetables, and improve the quality of horticultural products^[13-18]. H₂S fumigation on kiwifruit^[19], banana^[11], pear^[6] could retard softening and reduce decay, it can be seen that H₂S treatment can better delay fruit aging and maintain fruit storage quality after harvest. Therefore, in this study, 'Ziguo NO1' was used as the materials to explore the influence of H₂S treatment with different concentrations on the physiological and

quality change of cold-storage passion fruit, so as to provide production guidance for the preservation of passion fruit.

2 MATERIALS AND METHODS

2.1 Plant material and treatment

Passion fruit (*Passiflora edulis* Sims, 'Ziguo NO1') were obtained from a orchard in Hezhou, Guangxi. The high-quality fruits were selected at commercial maturity with uniform size, straight shape, without blemish and disease, mechanical injury. Whereafter, the fruits were transported into the lab immediately.

The fresh passion fruits were washed, and soaked with 500 mg/kg prochloraz for 2min, then air-dried. They were divided into 4 groups prior to treatments, placed into 0.1m³ PP seal box. 1 mmol/L, 2 mmol/L, 3 mmol/L NaHS solution and distill water (as control, CK) were put into 4 box respectively, the fumigation treatments were lasted

for 12h at ambient temperature. After fumigation, the fruits were wrapped with BOPP bags, each group was divided into 14 bags, which containing 6-8 fruits of each bag, and then placed in plastic fruit box, stored at 5±1°C.

The properties of control group were measured as the initial value on the day of treatment, 2 bags were taken as samples from each group every 7 days randomly, and then the quality analysis of pulp and peel was measured. The juice was squeezed out by 4 layers of gauze, the peel was treated with liquid nitrogen and stored at -80°C for further analysis. The experiment was repeated 3 times,

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and the average value was taken.

2.2 Evaluation of color

The color of passion fruit was determined by a colorimeter (NH310, Sanenshi Technology, Shenzhen), the measured points were symmetrically distributed around the equator of the fruit, and each fruit measured for 3 points, read the value of L^* , a^* , b^* . L^* stands for lightness, a^* shows chromaticity on a green (-) to red (+) axis, b^* shows chromaticity on blue (-) to yellow (+) axis.

2.3 Weight loss

Weight loss was calculated based on the formula using an electronic weighing scale (BSA2202S electronic weighing scale, Sartorius Scientific Instruments, Beijing) to record.

$$\text{Weight loss (\%)} = [(M_1 - M_2) / M_1] \times 100$$

With M_1 , initial fruit weight; and M_2 , final fruit weight after storage.

2.4 Determination of total soluble solids

Every 7 days, the juice of treated or control passion fruit was used for analysis of total soluble solids. Total soluble solids content was determined by using a refractometer (LH-B55Brix meter), and the results were expressed as %.

2.5 Analysis of total vitamin C (VC), titratable acidity (TA), sugar and soluble protein

Total vitamin C content was measured by the 2,6-dichloroindophenol titrimetric method^[20], with slight modification.

The titratable acidity was determined by titration with NaOH^[21], with slight change.

The determination of sugar was according to the method by Li et al.^[19], with slight modification.

Soluble protein content was measured according to the method of Bradford^[22].

2.6 Statistical analysis

Each measurement was performed by the SPSS version 22.0 statistical software, the data were subjected to one-way ANOVA. Duncan's multiple range tests were also used to determine the difference of means from the ANOVA. It was considered to be significant variation when differenced were at $p < 0.05$. The results were expressed as the means $\pm$ SD. Data graph was drawn by Origin version 8.5.

3 RESULTS

3.1 Effect of H₂S fumigation on color of passion fruit

The change in passion fruit peel color was calculated in Figure 1. Generally, Figure 1A showed a trend of decreasing firstly and then increasing, the L^* value of H₂S treatments were lower than that of CK, and after 21 d it was significantly lower than CK. Above all treatments, the value of H₂S with 3 mmol/L was higher than the others at 14 d and 21 d. In Figure 1B, a^* showed a trend of decreasing, the value of CK was lower than treatments, and the value of 2 mmol/L was the highest in all. In Figure 1C, b^* value decreased accompany with storage time. b^* value of 3 mmol/L was higher than others, but had no difference with 2 mmol/L.

Fig. 1. Effects of H₂S fumigation treatment on L^* (A), a^* (B) and b^* (C) in harvested Passion fruit

3.2 Effect of H₂S treatment on weight loss

As shown in Figure 2, H₂S treatments showed a slower weight loss than that of control fruits, although there were growing trends in all groups during the whole storage time. The weight loss of control was 6 times higher than H₂S treatment with 3mmol/L at 28 d. Compared with the three treatments, there were significant differences among them after 14 d.

Fig. 2. Effects of H₂S fumigation treatment on weight loss in harvested Passion fruit

3.3 Effect of H₂S treatment on total soluble solid

The total soluble solid content was increased with varying degrees during the first 14 d, after that the control group decreased rapidly (Figure 3). At the end of the storage, the content of 1 mmol/L, 2 mmol/L, 3 mmol/L H₂S treatment were reduced by almost 5.5%, 6.4%, 2.9%, which less than the control 8.5%. These results indicate that high H₂S can slow the decline of soluble solids in passion fruit.

Fig.3. Effects of H₂S fumigation treatment on TSS content in harvested Passion fruit

3.4 Effect of H₂S on total vitamin C, titratable acidity, sugar and soluble protein

The variation on vitamin C content was showed in Figure 4A. The content of VC was increased to the highest at 7 d or 14 d, then dropped notably during the late storage. However, H₂S treatment slowed the falling tendency, remarkable variation was founded in 2 mmol/L group ($p < 0.05$).

The changes of TA content were showed in Figure 4B. During the storage time, all the groups decreased, while H₂S treatments reduced the downward trend, after 14 d, they showed notable differences to the control ($p < 0.05$).

The sugar content before 14 d was increased, and there were no incredible difference (Figure 4C). Hereafter, the content of control decreased to 17g/100mL, while H₂S treatments reached to 20, 21, 20 g/100mL respectively at 35 d, only 2.2% less than the initial value.

The soluble protein content in all treated passion fruits increased during the first 7 days, but no significant differences among them were observed (Figure 4D). Thereafter, all groups reduced until the end of storage. However, the soluble protein content in passion fruits with 2 mmol/L H₂S remained higher than that in control.

Fig. 4. Effects of H₂S fumigation treatment on VC, TA, sugar and soluble protein content in harvested Passion fruit

4 DISSUSION

Passion fruit is a kind of tropic fruit, which is easy to lose water after harvest and cause wilting, resulting in loss is about 10-60% of the postharvested fruits^[23]. Therefore, reducing postharvest loss and maintaining fruit quality have become an important research content. H₂S involves in many important physiological progresses in plants, and it is the third gas signal molecule after NO and CO, which can promote photosynthesis and accumulation of organic matter, alleviate damages from various biological and abiotic stresses and promote plant growth and development, retard plant senescence^[5]. Studies on water spinach have found that H₂S fumigation can stimulate the generation of endogenous H₂S, then increase the antioxidation, reduce the respiration rate, and thus delay leaves yellowing and senescence^[24].

The color of peel can be used as an index of maturity of passion fruit, for purple passion fruit, the color from green to purple^[25]. In our study, we found that the skin of the control fruits become darker and purple, but fruits with H₂S could maintain bright color(Figure 1).

Postharvest senescence is always accompanied with water and nutrients loss, wilting. Studies have shown that water loss rate was increased during the storage time^[26], and aged plant lost water faster than non-senescencing plant^[27]. In this study, we also found that the water loss rate of passion fruit increased during cold storage, while H₂S treating reduced weight loss(Figure 2).

Sugar is consumed during storage time as the substrate of respiration, which also leads to the decrease of soluble solids^[3], and it was reported that the soluble solids content of passion fruit decreased significantly over 14 d at 10°C^[28], which is consistent with our results. During the ripening, the TSS, sugar, VC and soluble protein content increased, but decreased with aging, additional changes include TA decreasing, H₂S fumigation significantly slowed down the consumption of sugar and reduced the decrease trend of TSS, TA, VC and soluble protein (Figure 3 and 4), the reason for this may be that H₂S reduced respiratory expenditure, delayed the aging progress. These results were accordance with the study on strawberry^[9], banana^[12], grape^[29] and kiwifruit^[19].

5 CONCLUSION

Overall, the results revealed that application of 2 mmol/L H₂S maintained the best quality of passion fruit during cold storage. The data demonstrated that the lower weight loss rate, higher TSS, TA, VC, sugar and soluble protein contents with 2 mmol/L H₂S. Consequently, H₂S may be an effective way to keep the quality of passion fruit after harvesting. Furthermore, more molecular mechanisms are needed to be explained to improve the shelf-life of passion fruit.

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