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Anoxia Treatment for Delaying Skin Browning, Inhibiting Disease Development and Maintaining the Quality of Litchi Fruit

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Summary

Litchi fruit has a very short shelf life after harvest, so marketers and consumers alike desire longer periods of storage, transportation and distribution. To extend shelf life, anoxia treatments were used for the fruit. Litchi fruit were exposed to pure N_2 for 0, 3, 6, 12 or 24 h. They were then kept individually in closed but vented containers for 6 days in the dark at 20 °C and 95–100 % relative humidity. Exposure of litchi fruit to N_2 for 3 or 6 h markedly delayed skin browning, reduced rot development and maintained higher concentrations of total soluble solids, titratable acidity and ascorbic acid after 6 days of storage. Anoxia treatment for 24 h reduced browning index, but it accelerated disease development, compared to the control. Thus, a pre-storage pure N_2 treatment for 3 or 6 h can be an effective means of reducing rotting while maintaining the physical quality of the fruit.

Key words: anoxia, *Litchi chinensis*, quality, storage treatment

Introduction

Litchi (*Litchi chinensis* Sonn.) is a tropical and subtropical fruit of high commercial value for its white, translucent aril and attractive red colour. The major limitations in litchi marketing are the rapid loss of red colour and the decay of the fruit after harvest (*1*,*2*). Postharvest treatments, such as sulphur fumigation and acid dip, in combination with low temperature storage, can effectively delay the loss of red colour of the skin of litchi fruit, while the application of fungicides, such as thiabendazole and prochloraz, exerts effective control of spoilage pathogens (*2*,*3*). However, because of the concerns for food safety and restrictions in the use of chemicals, alternative means of colour and decay control in litchi fruit are needed (*4*,*5*).

Storage of fruit and vegetables under very low O_2 pressures may have beneficial effects, such as reducing respiration rate, inhibiting ethylene production and action, and reducing the incidence of some physiological disorders (*6–8*). Pretreatment of various fruit with anoxia can delay ripening (*7*,*9*). Fallik *et al*. (*10*) reported that a short-term anoxia treatment (for 24 h) significantly reduced rot development in tomato fruit inoculated with *Botrytis cinerea*, compared to non-treated fruit. In our preliminary investigations, however, the anoxia treatment was not very effective in inhibiting disease development of harvested banana fruit. Thus, the beneficial effects on the control of spoilage pathogens varied depending on different types of fruits.

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Unlike climacteric fruits such as tomato and banana, litchi fruit are non-climacteric, and will not continue to ripen once removed from the tree (*11*). The objective of this study was to evaluate the effect of a short pre-storage anoxia treatment on the development of decay and physical and sensory traits of litchi fruit.

Material and Methods

Litchi fruit (*Litchi chinensis* Sonn.) cv. Huaizhi at 80 % maturation was obtained from a commercial orchard in Guangzhou, China. The fruit was selected for uniformity of shape and colour and lack of blemished or diseased fruits. The fruit was placed inside a 4.2-L glass jar and flushed with 100 % N_2, which was purified by the supplier (Guangzhou Gas Factory) and used specially for this laboratory experiment, until the O_2 concentration in the jar was ≤0.05 % measured by an O_2 and CO_2 detector (Model CYES-II, Shanghai Scientific Instruments). Then, the fruits were kept for 3, 6, 12 and 24 h under humidified pure N_2 flow at 100 mL/min, described previously by Jiang and Fu (*12*). Fruit kept in humidified air for 24 h at the same flow rate as N_2 gas was used as control. In this study, 15 kg with approx. 1000 fruits was used for each treatment with three replications while all fruits were held at 20 °C and about 90 % relative humidity. After the above treatments for 3, 6 and 12 h, the fruit were removed from the jars, then transferred to humidified air at flow rate of 100 mL/min, with a total 24-h exposure to N_2 gas plus air, and finally kept in the dark at 25 °C and 95–100 % relative humidity in individual closed but vented containers (*13*). The experiments were repeated twice during the whole season. Similar results were obtained from the two experiments. The data from the second experiment are presented.

Fruit browning

Skin appearance was assessed by measuring the extent of the total browned area on each fruit pericarp of 30 fruits, using the following scale: 1 = no browning (excellent quality); 2 = slight browning; 3 = <1/4 browning; 4 = 1/4 –1/2 browning; 5 = >1/2 browning (poor quality). The browning index was calculated as Σ(browning scale × percentage of corresponding fruit within each class). The subjective evaluation of skin browning index correlated well with the objective determination of the absorbance value at 410 nm of the skin extract (*14*).

Disease incidence and postharvest life

The development of disease resulting from natural infection was assessed by observing visible fungal growth or bacterial lesions on the surface (*15*). Fruit was checked at 2-day intervals. Postharvest life was defined as the time from the harvest until the fruit reached 2.0 browning index, with no symptoms of disease.

Measurements of total soluble solids, titratable acidity and ascorbic acid

The contents of total soluble solids, titratable acidity and ascorbic acid of fruit exposed to N_2 for 6 days were analysed. Pulp (20 g) from 15 fruits without any symptoms of disease was homogenised in a grinder and the supernatant phase was collected to analyse total soluble solids, titratable acidity and ascorbic acid. Total soluble solids were assayed by using a hand refractometer (J1–3A, Guangdong Scientific Instruments), and titratable acidity and ascorbic acid were determined by titration with 0.1 M NaOH and 2,6-dichlorophenol indophenol, respectively.

Data handling

These experiments were arranged in completely randomized design, and each treatment comprised of three replicates. Data were tested by the analysis of variance using SPSS version 7.5. Least significant differences (LSDs) were calculated to compare significant effects at the 5 % level.

Results and Discussion

The major postharvest problem of litchi fruit is deterioration of visual appearance (browning) (*2*). Anoxia treatments markedly delayed browning index (Fig. 1). The best inhibition of the browning was observed in the fruit after the anoxia treatment was applied for 3 or 6 h. However, as anoxia treatment time was extended, the inhibition decreased. In this investigation, much higher level of ethanol production of the pulp was observed immediately after the exposure of litchi fruit to N_2 gas for 12 or 24 h, but there was no significant difference between the control and the treatment after 2, 4 or 6 days of storage. Similar reports were observed in apple and pear stored under low O_2 conditions (*16–18*). Recently, Saquet *et al.* (*18*) suggested that flesh browning of 'Conference' pear was associated with higher ATP concentrations in the fruit tissue, which might maintain membrane integrity. In this study, the reason of the reduced inhibition of browning of litchi fruit exposed to N_2 for 12 or 24 h may be a very limited amount of ATP, produced by alcoholic fermentation, resulting in the loss of the compartmentation between enzymes and their substrates, which cause enzymatic browning. However, the underlying biochemistry and physiology need further investigation.

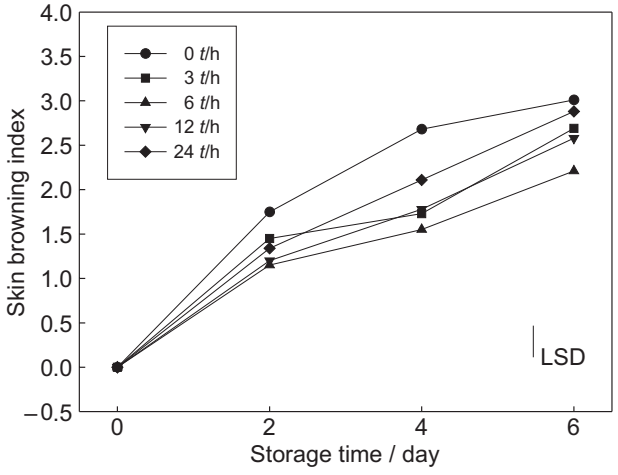

Fig. 1. The effect of anoxia treatments on skin browning index of litchi fruit during storage. LSD = least significant difference at 5 % level

The principal disease of litchi fruit was caused by *Peronophythora litchi* (*5*). The disease development was markedly reduced by exposure to N_2 for 3 and 6 h (Fig. 2). Exposure to N_2 for 12 or 24 h, however, accelerated the rate of disease development of the fruit during storage, as opposed to the exposure for 3 or 6 h. Thus, increasing anoxia treatment time from 0 to 6 h tended to progressively enhance the postharvest life, judged by skin browning index, without the development of disease (Fig. 3). One of the hypotheses for the mode of action of the anoxia treatment on decay is that the resistance of harvested litchi fruit to pathogens increased or decreased mainly by regulating physiological processes. Bonghi *et al*. (*19*) and Pesis *et al*. (*20*) reported that keeping fruit and vegetables in very low oxygen atmospheres reduced some physiological disorders and disease development. Longer exposure to anoxia environment resulted in an accelerated rot development of tomato in the late period of storage (*10*). Thus, the mode of action is still unclear and needs to be further investigated.

Total soluble solids, titratable acidity and ascorbic acid are important factors in flavour and nutritive quality of litchi fruit (*21*). As shown in Table 1, the contents of total soluble solids, titratable acidity and ascorbic acid of litchi flesh decreased markedly after 6 days of storage, particularly the concentration of ascorbic acid. Exposure of fruit to anoxia environment resulted in higher level of ascorbic acid and total soluble solids, but did not affect titratable acidity significantly. In addition, we found that anoxia treatment for 24 h resulted in an off-flavour of litchi fruit, which was probably due to the accumulation of ethanol inside the fruit (*22*).

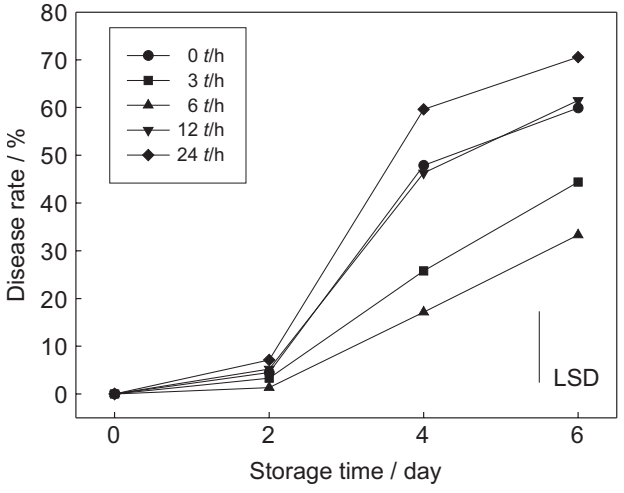

Fig. 2. The effect of anoxia treatments on rotting of litchi fruit during storage. LSD = least significant difference at 5 % level

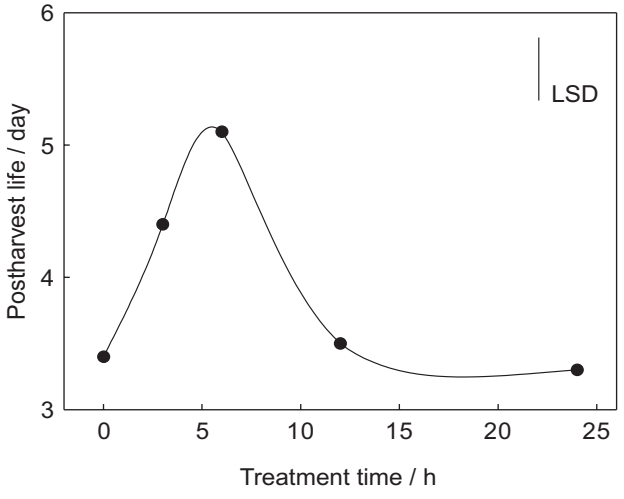

Fig. 3. The effect of anoxia treatments on postharvest life of litchi fruit. LSD = least significant difference at 5 % level

Table 1. Effects of anoxia treatments of litchi fruit after 6 days of storage at 25 °C

$t(N_2$ treatment)	w(total soluble solids)	w (total titratable acidity)	w(ascorbic acid in pulp)
h	%	%	(mg/100 g)
0	13.0^b	0.09^a	21.90^c
3	13.2^b	0.09^a	23.37^b
6	13.5^a	0.10^a	24.85^a
12	13.5^a	0.10^a	23.42^b
24	13.6^a	0.11^a	23.32^b

Each value is the mean value and standard error for three replicates. The contents of total soluble solids, titratable acidity and ascorbic acid of litchi fruit pulp at harvest were 16.8 %, 0.14 % and 41.82 mg/100 g, respectively. The mean values within a column followed by the same letter are not significantly different at the 5 % level

In conclusion, the efficacy of the anoxia treatment evidently depends on the length of the application. A pre-storage pure N_2 treatment for 6 h can be an effective means of reducing rots while maintaining the physical quality and overall taste of the fruit. However, the mode of action of the treatment is still unclear and, thus, needs further investigation. As a non-chemical and inexpensive postharvest technology, the anoxia treatment deserves further development, especially under commercial distribution conditions or in developing countries such as China where refrigeration is inadequate.

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References

1. P. K. Ray, *J. Food Sci. Technol. 35* (1998) 103–116.
2. Y. M. Jiang, L. H Yao, A. Lichter, J. R. Li, *J. Food Agric. Environ. 1* (2003) 76–81.
3. D. M. Holcroft, E. J. Mitcham, *Postharvest Biol. Technol. 9* (1996) 265–281.
4. L. Korsten, E. E. De-Villiers, E. S. De-Jager, M. W. S. Van--Harmelen, *Yearb. S. Afr. Litchi Grow. Assoc. 5* (1993) 36–40.
5. Y. M. Jiang, V. R. Zhu, Y. B. Li, *Lebensm. Wiss. Technol. 34* (2001) 430–436.
6. D. Ke, A. A. Kader, *Postharv. News Info. 3* (1992) 31–37.
7. E. Pesis, R. Marinansky, *J. Plant Physiol. 142* (1993) 717–721.
8. E. Pesis, R. Marinansky, G. Zauberman, Y. Fuchs, *Hortscience, 29* (1994) 1042–1046.

9. J. N. Burdon, S. Dori, E. Lomaniec, R. Marinansky, E. Pesis, *Ann. Appl. Biol. 125* (1994) 581–587.

10. E. Fallik, Y. Polevaya, S. Tuvia-Alkalai, Y. Shalom, H. Zuckermann, *Postharvest Biol. Technol. 29* (2003) 233–236.

11. R. E. Paull, J. N. Chen, *Sci. Hortic. 33* (1987) 223–236.

12. Y. M. Jiang, J. R. Fu, *J. Horticult. Sci. Biotechnol. 74* (1999) 43–46.

13. Y. M. Jiang, D. C. Joyce, L. Terry, *Postharvest Biol. Technol. 23* (2001) 227–232.

14. Y. M. Jiang, *J. Sci. Food Agric. 80* (2000) 305–310.

15. L. A. Terry, D. C. Joyce, *Pest Manag. Sci. 56* (1993) 989–992.

16. A. A. Saquet, J. Streif, F. Bangerth, *J. Horticult. Sci. Biotechnol. 75* (2000) 243–249.

17. J. Streif, H. Xuan, A. A. Saquet, C. Rabus, *Acta Hortic. 553* (2000) 635–637.

18. A. A. Saquet, J. Streif, F. Bangerth, *Postharvest Biol. Technol. 30* (2003) 123–132.

19. C. Bonghi, A. Ramina, B. Ruperti, R. Vidrih, P. Tonutti, *Postharvest Biol. Technol. 16* (1999) 213–222.

20. E. Pesis, A. Copel, R. Ben-Arie, O. Feygenberg, Y. Aharoni, *J. Horticult. Sci. Biotechnol. 76* (2001) 648–652.

21. Y. M. Jiang, J. R. Fu, *Trop. Sci. 36* (1998) 155–159.

22. M. O. Kelly, M. E. Saltveit, *Plant Physiol. 88* (1988) 143–147.

Anoksična obrada radi usporavanja posmeđivanja kore, inhibiranja razvoja bolesti i održavanja kakvoće ploda liči

Sažetak

Plodovi liči nakon branja vrlo se kratko održavaju pa prodavači i potrošači traže duži vijek trajanja za njihovo skladištenje, transport i prodaju. Da bi se produljilo to trajanje, plodovi liči su bili izloženi čistome dušiku tijekom 0, 3, 6, 12 ili 24 sata (anoksična obrada). Voće je čuvano individualno u zatvorenim kontejnerima s otvorima tijekom 6 dana u tami pri 20 °C i 95–100 % relativne vlažnosti. Izlaganje ploda liči dušiku tijekom 3 ili 6 sati bitno je usporilo posmeđivanje kore, smanjilo truljenje ploda i zadržalo veliku koncentraciju ukupnih topljivih tvari, kiselosti i askorbinske kiseline nakon 6 dana skladištenja. Anoksična obrada tijekom 24 sata snizila je indeks posmeđivanja, ali je u usporedbi s kontrolnim uzorkom ubrzala razvoj bolesti. Stoga je obrada čistim dušikom tijekom 3 ili 6 sati prije skladištenja djelotvoran način smanjivanja truleži zadržavajući svojstva svježega voća.