Effect of 1-MCP treatments on 'Hanfu' apples during long cold storage

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Keywords: 'Hanfu' apple, 1-MCP, storage physiology, cold storage

Abstract. The experiment aimed to evaluate the effect of 1-MCP treatment on postharvest 'Hanfu' apple. The fruits were treated with 0, 0.3, 0.6 and 0.9μL·L^{-1} 1-MCP before put in cold storage condition (2±0.2˚C) with modified atmosphere package for 240d. The storage quality and physicochemical change were measured and the results showed: Compare with CK, the respiration and ethylene peaks of treat B were significantly lower ($p<0.01$). The peaks arrivals were delayed for 15d and 20d. The hardness, SSC and TAC of fruits treated kept at a relatively higher level. CAT, POD and SOD activities were found to be improved significantly ($p<0.01$). Treat B and treat C were both effective and treat B (0.6μL·L^{-1}) was regarded as the appropriate concentration to store 'Hanfu' apple during long cold storage.

Introduction

'Hanfu' apple ('Dongguang'× 'Fuji') is a cold-tolerant, large apple cultivar bred by Shenyang Agricultural University, China [1]. Now it has become the second-largest apple cultivar in Liaoning province and was regarded as the main cultivar with 'Fuji', 'Jonagold' and 'Marshal' [2]. It is necessary to research the fresh-keeping technique for the fine quality cultivar.

Ethylene is plant endogenous hormone and closely related to the speed of ripening and aging. 1-Methylcyclopropene (1-MCP) interacts with ethylene receptors and prevents ethylene-dependent responses [3]. It is the basis of a new technology that is increasingly being used to improve postharvest life and maintain quality of many horticultural products, such as pears [4], persimmon [5], and apples [6]. The beneficial effects of 1-MCP have been well recognized [7]. However, a little information concerning 1-MCP influences on 'Hanfu' apple quality is available. Liu et al. believed that 'Hanfu' apple was a storable cultivar and the storage had little effect on fruit quality [1]. Wei et al. reported 1-MCP and its structural analogue were effective on 'Hanfu' apple room temperature storage [8]. Cheng etc. suggested that modified atmosphere packaging combined with 1-MCP (0.75μL·L^{-1}) treatment had the potential to inhibit the physiological decrease [9]. Tong etc. concluded that 1-MCP could obviously delay fruit senescent and the 1.0μL·L^{-1} was the optimum concentration [10]. Though more recent studies focused on the effects of 1-MCP, the results seemed inconsistent and complicated. So, the aim of this study was to evaluate the effect of the postharvest treatment by (1-MCP) on the apple physicochemical quality and provide a basis for the application.

Materials and methods

Storage trials were conducted with 'Hanfu' apples in 2012. All apples were harvested from a commercial orchard located in Shenyang. All apples were chosen for uniform size, consistent color, no pests and suitable maturity (80%-90%), and shipped back to the lab within 3h. 0.14% 1-MCP

powder produced by Rohm and Hass China Inc.

1-MCP treatments First 20 'Hanfu' apples were reserved randomly for the initial value determination. The apples were divided into four parts put into four $1m^3$ plastic tents. Treatment method was followed Sun [11]. Three treatments: treat A, $0.3\mu L \cdot L^{-1}$; treat B, $0.6\mu L \cdot L^{-1}$; treat C: $0.9\mu L \cdot L^{-1}$. Distilled water was as control (CK). All tents were sealed immediately and placed at room temperature for 24h in order to fumigate apples with 1-MCP, and then put into PE fresh bag. All the bags tied, transferred to cold storage at 2˚C±0.2˚C preserved for 240d.

Sample methods and determination Sample methods: three fruits selected randomly from each treatment, three points each fruit were taken. Three replicates. Respiration rate and ethylene production were measured once every 15d; activity of antioxidant enzymes and quality indicators tested once every 30d. Physiological and biochemical indicators were measured after balance at 20˚C for 24h.

Respiration rate was measured with an O_2/CO_2 analyzer, and the unit was mg $CO_2 \cdot kg^{-1} \cdot h^{-1}$. Internal ethylene concentration was determined with CP-3800 gas chromatograph, Varian, Inc. The unit was $\mu L \cdot kg^{-1} \cdot h^{-1}$. Flame ionization detector and the column temperatures were 270˚C and 60˚C. Nitrogen was as the carrier gas at a flow rate of $4.0mL \cdot min^{-1}$. The unit was $\mu L \cdot kg^{-1} \cdot h^{-1}$. Hardness determined with a FT-327 hardness tester. Soluble solids content (SSC) determined with a TD-45 digital sugar meter. Titratable acid content (TAC) was determined by acid-base titration. Catalase (CAT) activity ($\triangle OD_{240} \cdot min^{-1} \cdot g^{-1}$) was determined with hydrogen peroxide consumption method according to Cao ea al [12]. Peroxidase (POD) activity ($\triangle OD_{470} \cdot min^{-1} \cdot g^{-1}$) was determined with Guaiacol method according to Jiang et al [13]. Superoxide disproportionation enzymes (SOD) activity ($U \cdot g^{-1}$) was determined with Nitroblue tetrazolium reduction method (NBT) according to the method of Wang et al [14].

Statistics All the experimental data were calculated, plotted with Microsoft Excel 2003, and compared with the difference significance between the treatments with DPS2000, Duncan: significant ($p<0.05$); highly significant ($p<0.01$).

Results and discussion

The respiration rates increased gradually to reach the peak at the early stage and then slowed down at the latter stage both in CK and three treatments fruits (Fig.1). The peaks arrival treated were delayed for 15d. The respiration peaks of the treatments were lower than that of CK highly significant ($p<0.01$). The value of treat B was 81.43% of CK, $73.4mg \cdot kg^{-1} \cdot h^{-1}$, and was the lowest. The internal ethylene productions increased gradually to reach the peak then slowed down (Fig.2). The ethylene peaks were delayed for about 15d because of treating with 1-MCP. The peaks value of treatments were lower than that of CK highly significant ($p<0.01$) especially from 45d to 120d. The peaks value of treat B and treat C were lower than that of treat A ($p<0.05$), but the difference between B and C was not significant ($p>0.05$).

The results suggested that 1-MCP effectively inhibited the respiration rate and the internal ethylene production in 'Hanfu' apple. These were consistent with 'Huahong' [15] and 'Gala' [16]. Also, the fact that the two peaks were delayed was consistent with that of 'Jinguan' [17]. It was assumed that amount of ethylene release probably promoted the respiration peaks' arrival.

The hardness was decline slowly. At early 60d no difference was seen between CK and treatments. After 90d, CK and treat A declined rapidly, and treat B and C declined mildly. At the end of stage, the hardness values of CK, treat A, B and C were 5.33 $kg \cdot cm^{-2}$, 5.97$kg \cdot cm^{-2}$, 6.42$kg \cdot cm^{-2}$ and 6.53$kg \cdot cm^{-2}$, respectively. Among the treatments, treat C was 22.51% higher than CK; treat B was 20.45%. No significant difference was seen between them according to the data analysis (P＞

0.05), but treat B seemed milder compared with treat C (Fig.3). SSC was decline during the storage. CK declined from 14.5% to 10.3%, and the treatments declined to 10.8%, 10.9% and 11.2%. Treat C was the highest, 8.73% higher than CK. Among them, treat B and C was significantly higher than CK and treat A ($P<0.01$), but the difference between treat B and C was not significant ($P>0.05$) (Fig.4). TAC was declining continuously. CK was lower than the three treatments all the time. At the time of 240d, the TAC values were 0.071%, 0.095%, 0.131% and 0.165%, respectively. TAC of treat C was the highest, 132.39% higher than CK. The deference between CK and three treatments was extremely significant ($P<0.01$) (Fig.5).

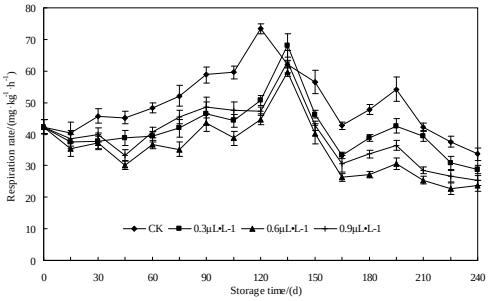

Fig.1 Effects of 1-MCP treatments on respiration rate

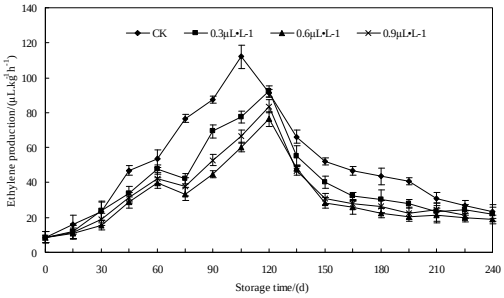

Fig.2 Effects of 1-MCP treatments on internal ethylene production

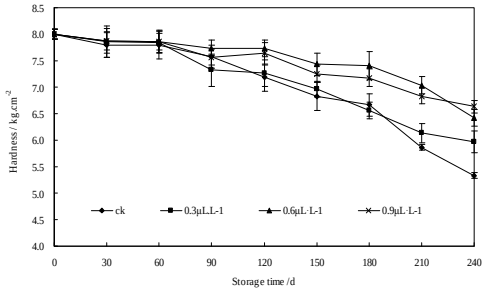

Fig.3 Effects of 1-MCP on fruits hardness

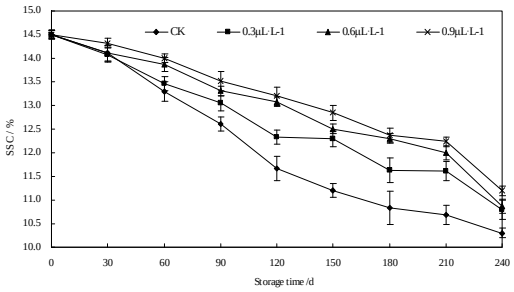

Fig.4 Effects of 1-MCP on fruits SSC

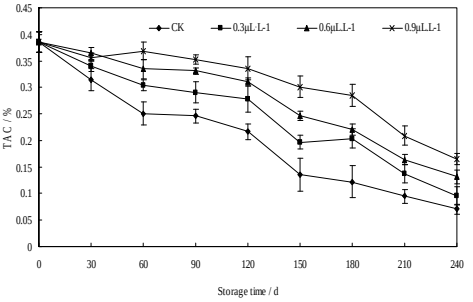

Fig.5 Effects of 1-MCP on fruits TAC

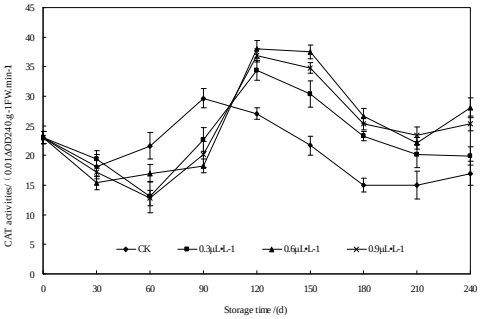

Fig.6 Effects of 1-MCP on fruits CAT activities

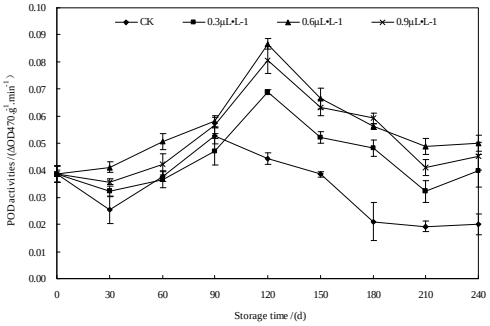

Fig.7 Effects of 1-MCP on fruits POD activities

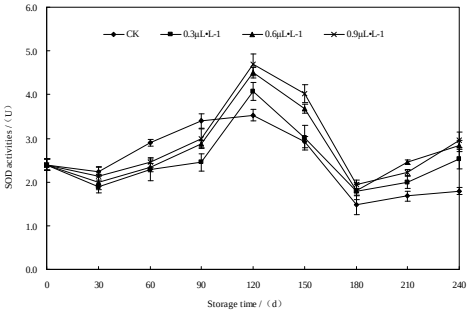

Fig.8 Effects of 1-MCP treatments on SOD activities

The activities of three antioxidant enzymes, CAT, POD and SOD, increased and declined during the cold storage. The CAT and POD activity peaks of CK arrived at 90d while treatments at 120d. At 240d, CAT of treat B was 55.63% higher than CK and was the highest (Fig.6). For the POD activity, the difference was extremely significant between CK and the treatments ($p<0.01$). Treat B was 55.63% higher than CK and was the highest, but no significant difference was found between treat B and C (Fig.7). As for the SOD, the activities increased gradually until 120d, then decreased rapidly until 180d, and then increased slightly. CK arrived at 100d, while treatment at 120d. At the end, the difference was extremely significant between CK and the treatments ($p<0.01$). Treat B was 64.97% higher than CK and was the highest, but no significant difference was found between treat B and C (Fig.8).

In fact, enzyme activity was affected by multiple factors. SOD activity of 'Empire' apple treated remained relatively unchanged at 0.5◦C. CAT activity was initially lower in treated fruit stored, and then increased than CK [6]. Another example, compared to CK, the treated fruits exhibited higher CAT and lower POD activities. POD activity was especially inhibited by 1-MCP in persimmon [5]. 1-MCP treatment led to decrease levels of H_2O_2 and lipid peroxidation, concomitant with increased activities of CAT and SOD, as compared to respective controls in mango [18]. Leaf vegetable, such as coriander, was observed a significant increase in SOD, CAT and POX enzyme activities in 1-MCP treated leaves stored at 5˚C [19].In this study, treatments activities increased at early stage and declined after 120d during the later period. The results were not the same compared with the previous research. It seems more complex for effects of 1-MCP on the antioxidase activities because of different agricultural products and other factors.

Conclusion

In summary, compared with the control, 1-MCP effectively restrained the respiration rate and ethylene production of 'Hanfu' apple during long-term cold storage. The respiration and ethylene peaks of treat B were 59.8mg·kg^{-1}·h^{-1} and 76.4μL·kg^{-1}·h^{-1}, significantly lower than that of CK ($p<0.01$). The respiration peaks and ethylene peaks arrival treated with 1-MCP were delayed for 15d. The fruit quality including hardness, SSC and TAC of fruits treated with 1-MCP kept at a relatively higher level than those of CK. CAT, POD and SOD activities were tested to be improved by 1-MCP treating and played roles in protecting the fruits from the reactive oxygen species damage especially at the latter period. Treat B (0.6μL·L^{-1}) and treat C (0.9μL·L^{-1}) were both effective and treat B was regarded as the appropriate treatment to store 'Hanfu' apple in cold storage for long term.

Acknowledgement

This work was supported by project 'Hanfu' apple processing assessment and commercialized processing techniques shared services (F11253400).

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