ISSN 0101-2061 (Print)
ISSN 1678-457X (Online)
Food Science and Technology

CC BY

DOI: https://doi.org/10.1590/1678-457X.21816

Effects of 1-methylcyclopropene on texture properties of Rabbiteye blueberry during long-term storage and simulated transportation

Guofang XIE[1,2]*, Xinhua WANG[1,2], Kaihong WEI[1,2], Rui WANG[1,2], Sen CAO[1,2], Ning JI[1,2], Xiuzhong YANG[3]

Abstract

In this work, the effects of 1-methylcyclopropene (1-MCP) on texture properties, titratable acidity (TA) and total soluble solids (TSS) in blueberry were examined during long term storage and simulated transportation. Blueberry fruits were stored at 0 ± 0.5 °C after being treated with 0.1, 0.2 and 0.3μL L^{-1}1-MCP. After 40 and 80 days of storage, quickly put 8 punnets into a foam box with commercial cold pack to simulate the commercial transportation for 2 days at 25 °C. There were considerable differences in the texture properties during long term storage and simulated transportation with 1-MCP. The 0.3 μL L^{-1} 1-MCP can effectively decreased the decline of gumminess and chewiness, retarded the reduction of TA, and delayed blueberry fruit softening. There was significant positive correlation among firmness, springiness, cohesiveness, gumminess, chewiness, resilience, TSS, and TA. These results demonstrate that the 0.3 μL L^{-1} 1-MCP combines with commercial polyethylene bags were successful effect in maintaining the texture properties of blueberry.

Keywords: Rabbiteye blueberry; 1-MCP; texture properties; simulated transportation.

Practical Application: Evaluating the effectiveness of 1-MCP in maintaining blueberry texture during long term storage plus transport.

1 Introduction

Rabbiteye Blueberry (*Vacciniumashei*) is a climacteric fruit and soft fruit (Dan & Nesmith, 2011). Texture is one of the main quality parameters accepted by consumers, including eating quality, and storability during handling, postharvest storage and transportation (Li et al., 2011a). The texture properties mainly include firmness, springiness, cohesiveness, gumminess, chewiness, and resilience. The decrease in firmness lead to fruits softening, could be the reliable parameters of texture properties evaluation of soft fruits (Li et al., 2011a, b; Tian et al., 2011; Jia et al., 2014). There was significant positive correlation between commodity rate, fruits softening, firmness, cohesiveness, springiness, gumminess, chewiness, and resilience, respectively. The firmness had a significant positive correlation with TSS and TA (Ji et al., 2014; Wang et al., 2014).

1-methylcyclopropene (1-MCP) is used to maintain the postharvest quality and subsequent shelf life of blueberry (Delong et al., 2003; Chiabrando & Giacalone, 2011; Ji et al., 2014; Wang et al., 2014; Wang et al., 2015). The previously found that 1-MCP can effectively delays the drop of fruit crispness, firmness, springiness, cohesiveness, chewiness, resilience, commodity rate and inhibits fruit softening during storage, including 'Fuyu' persimmon (Argenta et al., 2009), Zizyphusjujube (Xie et al., 2009), pears (Wang et al., 2013a; Rizzolo et al., 2015), grape (Li et al., 2011b; Tian et al., 2011), tomato (Jeong, 2004; Zheng & Li, 2007), and apple (Li et al., 2013; Jia et al., 2014).

There is little scientific literature pertaining to use 1-MCP treatments on texture properties of blueberries during storage and transportation. Moreover, the effects of 1-MCP on texture properties of blueberry during storage and transportation had still not been reported. Thus, the objective of this study is to assess the effects of 1-MCP on texture properties of rabbiteye blueberry of 'Gardenblue' fruit during long-term storage and simulated transportation.

2 Materials and methods

2.1 Plant material

'Gardenblue' blueberry is grown in orchard, Majiang county, Guizhou province, in China. The blueberry fruits were hand-harvested on July 15, 2015, at 90% maturity (the fruit is blue and pedicel slightly red). Damaged and rotten blueberry fruits were eliminated, the fruits of uniform size without obvious damage were placed into 125 g punnets and transported to Guizhou engineering research center for fruit processing.

2.2 1-MCP treatment and storage conditions

The 288 punnets were randomly divided into four lots, each treatment for 72 punnets, the 12 punnets was packed into a commercial polyethylene bags, then transferred to cold storage, precooling at 1 °C for 12 h. The 0.14% 1-MCP (SmartFresh^{TM}, Agrofresh Inc., USA) was used to create 0.0, 0.1, 0.2 and 0.3 μL L^{-1} in commercial polyethylene bags. After the treatment, the all fruits were stored at 0 ± 0.5 °C, 85% ~ 95% R.H., 12 punnets per 1-MCP treatment were sampled at 0, 20, 40, 60, and 80 days after storage, determined the texture properties, TSS and TA after removal of rotten fruit.

Received 11 Aug., 2016
Accepted 04 Nov., 2017
[1] Food and Pharmaceutical Engineering Institute, Guiyang University, Guiyang, Guizhou, China
[2] Guizhou Engineering Research Center for Fruit Processing, Guiyang University, Guiyang,Guizhou, China
[3] Forestry Industry Office of Qiandongnan Prefecture, Kaili, Guizhou, China
*Corresponding author: xieguofang616@sina.com

2.3 Simulated Commercial transportation conditions

Commercial transportation of Guizhou highway road conditions was simulated by using transportation simulator. After 40 and 80 days of storage, quickly put 8 punnets into a foam box with commercial cold pack to simulate the commercial transportation conditions at the average velocity of 100 km/h for 2 days at 25 °C. 12 punnets per 1-MCP were analyzed for texture properties, TSS and TA for three replicates.

2.4 Texture properties

The force-time curves of blueberry fruits were determined by using a P/36R of TA.XT Plus texture profile analyzer (Stable Micro System Ltd., UK). The force was measured with the following instrumental settings: 2 mm/s of test speed, 1 mm/s of post-test speed, and auto-force trigger of 5.0 g. Each fruit was compressed and deformed to 30%. Thirty replicates, the same size fruits, were conducted for each treatment, the firmness, springiness, cohesiveness, gumminess, chewiness, and resilience were determined based on the force-time curve (Singh et al., 2013).

2.5 TA and TSS

TA was determined in triplicate by pH Meter (model PHS-3C, INESA Scientific Instrument Co., Ltd, Shanghai, China), using 0.1 N NaOH up to the pH 8.2, and expressed as g citric acid kg^{-1} (Xie et al., 2016). TSS of fruits were measured in triplicate using a hand-held refractometer (PAL-1, ATAGO, Tokyo, Japan) at 25 °C and expressed as % (Xie et al., 2015).

2.6 Statistical analysis

This study was executed by using a randomized factional experimental design. Statistical tests were carried out using the SPSS® Computer program, Version 22.0 (SPSS Statistical Software, Inc., Chicago, IL, USA). Significant differences between different storage time and treatments by using Duncan's multiple range test at the 5% level. The overall value and their comparison were used when the interactions were discovered not significant.

3 Results and discussion

3.1 Firmness

Fruit firmness of blueberry is an important parameter to evaluate the fruit softening. The firmness in control and 0.1 μL L^{-1}1-MCP treated blueberries decreased during 80 days of storage. However, the firmness in 0.2 μL L^{-1} and 0.3 μL L^{-1} 1-MCP treated blueberries increased then decreased during storage (Table 1), the firmness increase with the water loss after harvest was previously found by Allan-Wojtas et al. (2001) and Chiabrando & Giacalone (2011). The firmness of blueberry fruit treated with 0.3 μL L^{-1} 1-MCP was maintained at higher levels. The 0.3 μL L^{-1} 1-MCP can effectively delay the decrease of blueberries firmness after 80 days of storage plus 2 days transportation. These data clearly indicated that 0.3 μL L^{-1} 1-MCP delayed the softening of blueberry fruit. Retention of blueberry fruits firmness is of great importance during long term storage and transportation. This work reported that 1-MCP treatments conquered decline in firmness of blueberry fruit. Similar to firmness, certain reports claim that 1-MCP retard the reduction in firmness and delay the softening of blueberry (Dan & Nesmith, 2011; Wang et al., 2013b, 2014; Ji et al., 2014; Wang et al., 2015).

3.2 Springiness

In this study, the springness of all treatment blueberries decreased during storage and simulated transportation (overall values) (Table 1), the springness of blueberries treated with 0.3 μL L^{-1}1-MCP was maintained at higher levels. The blueberries treated with 0.3 μL L^{-1}1-MCP can effectively delay in this decrease of blueberry springiness after 80 days of storage plus 2 days transportation. These changes occurred much slower in the blueberries treated with 0.2 and 0.3 μL L^{-1} 1-MCP than the blueberries treated with control and 0.1 μL L^{-1} 1-MCP. The previously reported that 1-MCP delayed springiness changes in grape (Li et al., 2011b), pears (Wang et al., 2013a).

3.3 Cohesiveness

The cohesiveness of all treatment blueberries is decreased until to 40 days then progressively increased during 80 days of storage (Table 1). The cohesiveness of blueberries treated with 0.2 μL L^{-1} 1-MCP was retained at higher levels, the 0.3 μL L^{-1}1-MCP treatment can effectively delay the decrease of blueberry cohesiveness after 80 days of storage plus 2 days transportation. As in our study, the cohesiveness of blueberries is not affected by 1-MCP treatments, in agreement with jujube (Xie et al., 2009) and apple (Li et al., 2013; Jia et al., 2014). However, delay in the changes of cohesiveness was recorded for grape (Li et al., 2011b) and pear (Wang et al., 2013b).

3.4 Gumminess

The gumminess of blueberries in control and treated with 0.1 μL L^{-1} 1-MCP decreased during storage and simulated transportation. However, the gumminess of blueberries treated with 0.2 and 0.3 μL L^{-1} 1-MCP increased until to 40 days of storage then reduced during storage and simulated transportation (Table 1). The 0.2 and 0.3 μL L^{-1}1-MCP were more effective treatments in maintaining higher gumminess (overall) during storage and simulated transportation. The reduction in gumminess loss of fruit treated with 1-MCP is in agreement with fruit senescence.

3.5 Chewiness

The all treatments chewiness decreased during storage and storage plus 2days transportation (Table 1). The fruits treated with 1-MCP showed slightly higher than the control, and the difference among the treatment during storage and simulated transportation. The fruits treated with 0.3 μL L^{-1} 1-MCP were the most effective in maintaining higher chewiness level (overall values) during storage and simulated transportation. This result shows that the 1-MCP concentrations had a positive impact on the blueberry chewiness. Previous studies demonstrated that 1-MCP delayed the drop of grape chewiness (Li et al., 2011b), pear (Wang et al., 2013b), apple (Li et al., 2013; Jia et al., 2014), and peppers (Guo et al., 2015).

Table 1. Texture properties during storage and simulated transportation.

Testing index	Treatments	Storage and simulated transportation time (days)							
		0	20	40	60	80	40+2	80+2	Overall
Firmness (N)	Control	17.81^{cd}	17.50^{cd}	14.28^{f}	12.22^{ij}	9.98^{jk}	12.94^{ghi}	10.88^{kl}	13.66^{D}
	0.1 μL L^{-1} 1-MCP	17.81^{cd}	16.97^{d}	15.53^{e}	12.73^{hi}	9.85^{klm}	12.97^{ghi}	12.90^{ghi}	14.11^{C}
	0.2 μL L^{-1} 1-MCP	17.81^{cd}	18.40^{bc}	17.59^{cd}	13.28^{fghi}	10.20^{m}	$13.11f^{ghi}$	11.10^{jkl}	14.50^{B}
	0.3 μL L^{-1} 1-MCP	17.81^{cd}	$19.79a^{a}$	19.17^{ab}	14.10^{fg}	11.65^{lm}	14.24^{f}	13.76^{fgh}	15.79^{A}
	Overall	17.81^{b}	18.79^{a}	16.64^{c}	13.08^{d}	10.42^{f}	13.32^{d}	12.16^{e}	
Springiness	Control	0.77^{a}	0.74^{b}	0.73^{c}	0.74^{b}	0.69^{h}	0.68^{h}	0.64^{i}	0.71^{A}
	0.1 μL L^{-1} 1-MCP	0.77^{a}	0.73^{bc}	0.74^{b}	0.69^{gh}	0.69^{gh}	0.72^{cd}	0.70^{efgh}	0.72^{A}
	0.2 μL L^{-1} 1-MCP	0.77^{a}	0.71^{cde}	0.71^{defg}	0.71^{bcd}	0.70^{fgh}	0.74^{b}	0.71^{cde}	0.72^{A}
	0.3 μL L^{-1} 1-MCP	0.77^{a}	0.75^{b}	0.74^{b}	0.70^{fgh}	0.70^{fgh}	0.74^{b}	0.70^{efgh}	0.73^{A}
	Overall	0.77^{a}	0.73^{b}	0.72^{bc}	0.71^{bc}	0.70^{bc}	0.72^{b}	0.69^{c}	
Cohesiveness	Control	0.39^{e}	0.36^{i}	0.34^{j}	0.41^{d}	0.39^{e}	0.43^{c}	0.37^{fgh}	0.36^{B}
	0.1 μL L^{-1} 1-MCP	0.39^{e}	0.37^{ghi}	0.33^{j}	0.43^{bc}	0.41^{d}	0.41^{d}	0.38^{efh}	0.39^{AB}
	0.2 μL L^{-1} 1-MCP	0.39^{e}	0.38^{ef}	0.33^{j}	0.41^{d}	0.47^{a}	0.43^{c}	0.37^{fgh}	0.40^{A}
	0.3 μL L^{-1} 1-MCP	0.39^{e}	0.36^{hi}	0.33^{j}	0.36^{hi}	0.44^{b}	0.43^{bc}	0.38^{ef}	0.39^{AB}
	Overall	0.39^{ab}	0.37^{ab}	0.33^{b}	0.42^{a}	0.41^{a}	0.42^{a}	0.38^{ab}	
Gumminess	Control	203.11^{bc}	192.04^{cdef}	170.62^{ghij}	160.29^{ijk}	144.53^{lmn}	155.29^{klm}	120.93^{o}	163.83^{C}
	0.1 μL L^{-1} 1-MCP	203.11^{bc}	195.16^{cde}	185.59^{defg}	171.05^{ghij}	154.77^{klm}	175.08^{ghi}	138.50^{n}	174.75^{B}
	0.2 μL L^{-1} 1-MCP	203.11^{bc}	211.09^{ab}	185.23^{defg}	180.09^{efgh}	156.89^{jkl}	171.19^{ghij}	140.75^{mn}	178.34^{B}
	0.3 μL L^{-1} 1-MCP	203.11^{bc}	223.74^{a}	196.61^{cd}	183.52^{efgh}	168.38^{hijk}	178.22^{fgh}	142.20^{lmn}	185.11^{A}
	Overall	203.11^{a}	205.51^{a}	184.5^{1b}	173.74^{c}	156.14^{d}	169.9^{5c}	155.60^{d}	
Chewiness (g)	Control	156.92^{a}	137.27^{b}	122.61^{cdef}	121.69^{def}	97.88^{gh}	109.19^{fg}	87.72^{h}	119.18^{C}
	0.1 μL L^{-1} 1-MCP	156.92^{a}	139.83^{b}	133.49^{bcd}	127.26^{bcde}	110.80^{fg}	128.73^{bcde}	97.61^{gh}	127.81^{B}
	0.2 μL L^{-1} 1-MCP	156.92^{a}	140.33^{b}	132.66^{bcd}	132.63^{bcd}	118.29^{ef}	130.40^{bcde}	97.79^{gh}	129.80^{B}
	0.3 μL L^{-1} 1-MCP	156.92^{a}	154.71^{a}	136.58^{bc}	137.91^{b}	121.98^{def}	132.45^{bcde}	99.47^{gh}	134.29^{A}
	Overall	156.92^{a}	143.04^{b}	131.34^{c}	129.87^{c}	112.24e	125.19d	95.65f	
Resilience	Control	0.17^{de}	0.16^{fg}	0.15^{hij}	0.18^{cd}	0.15^{ghij}	0.18^{cd}	0.14^{lm}	0.15^{A}
	0.1 μL L^{-1} 1-MCP	0.17^{de}	0.16^{f}	0.15^{ijk}	0.19^{b}	0.15^{ghi}	0.18^{cde}	0.14^{kl}	0.16^{A}
	0.2 μL L^{-1} 1-MCP	0.17^{de}	0.17^{e}	0.15^{ijk}	0.18^{cd}	0.18^{bc}	0.18^{cd}	0.14^{lm}	0.16^{A}
	0.3 μL L^{-1} 1-MCP	0.17^{de}	0.16^{fgh}	0.15^{ijk}	0.20^{a}	0.13^{m}	0.18^{cd}	0.15^{jk}	0.16^{A}
	Overall	0.17^{ab}	0.16^{ab}	0.15^{b}	0.19^{a}	0.15^{b}	0.18^{a}	0.14^{b}	

Different letters in each column represent significant differences between the ripe stage ($P < 0.05$). All measures were performed in three independent samples.

3.6 Resilience

The resilience showed no consistent change during storage and transportation. Resilience of all treatment blueberries is decreased until to 40 days of storage then rose (Table 1). In this study, the resilience linearly decreased with storage time(overall), 1-MCP had no effects on the blueberries resilience during storage and transportation. The decline in resilience of blueberries treated with 0.2 μL L^{-1} 1-MCP was slower than other treatments. This result shows that the 1-MCP had a slightly effect on the resilience of the blueberry. Similar to our study, there were negligible differences on resilience for grape by1-MCP treatments (Li et al., 2011b). However, 1-MCP had a significantly effect on the resilience of pear (Wang et al., 2013b) and apple (Li et al., 2013; Jia et al., 2014).

3.7 TA and TSS

The TA in all treatment blueberry increased until to 20 days or 40 days, then decreased during storage (Figure 1A), however, the TA of blueberries for 80 days of storage plus 2 days transportation was significantly higher than that of stored at80 days. The TA of blueberries treated with 0.3 μL L^{-1}1-MCP was kept at lower levels after 80 days of storage plus 2 days of simulated transportation. These changes of blueberries treated with 0.3 μL L^{-1}1-MCP occurred much slower than other treatment. Similar to our study, 1-MCP can effectively delay the drop of TA in blueberry (Dan & Nesmith, 2011; Chiabrando & Giacalone, 2011; Ji et al., 2014), it mainly by regulating the balance between malate biosynthesis and degradation (Liu et al., 2016).

TSS is a key factor for fruit quality and acceptability of soft fruit. TSS changes of all treatment blueberries during storage and simulated transportation are showed in Figure 1B. TSS level at the preliminary stage of storage was 15.97% and decreased gradually during storage and simulated transportation in all treatment blueberries. As in this study, in Austin, Bright well, and Premier, TSS was minimal affected by 1-MCP (Dan & Nesmith, 2011). However, 1-MCP retard the decrease of TSS was recorded for blueberry (Chiabrando & Giacalone, 2011; Ji et al., 2014).

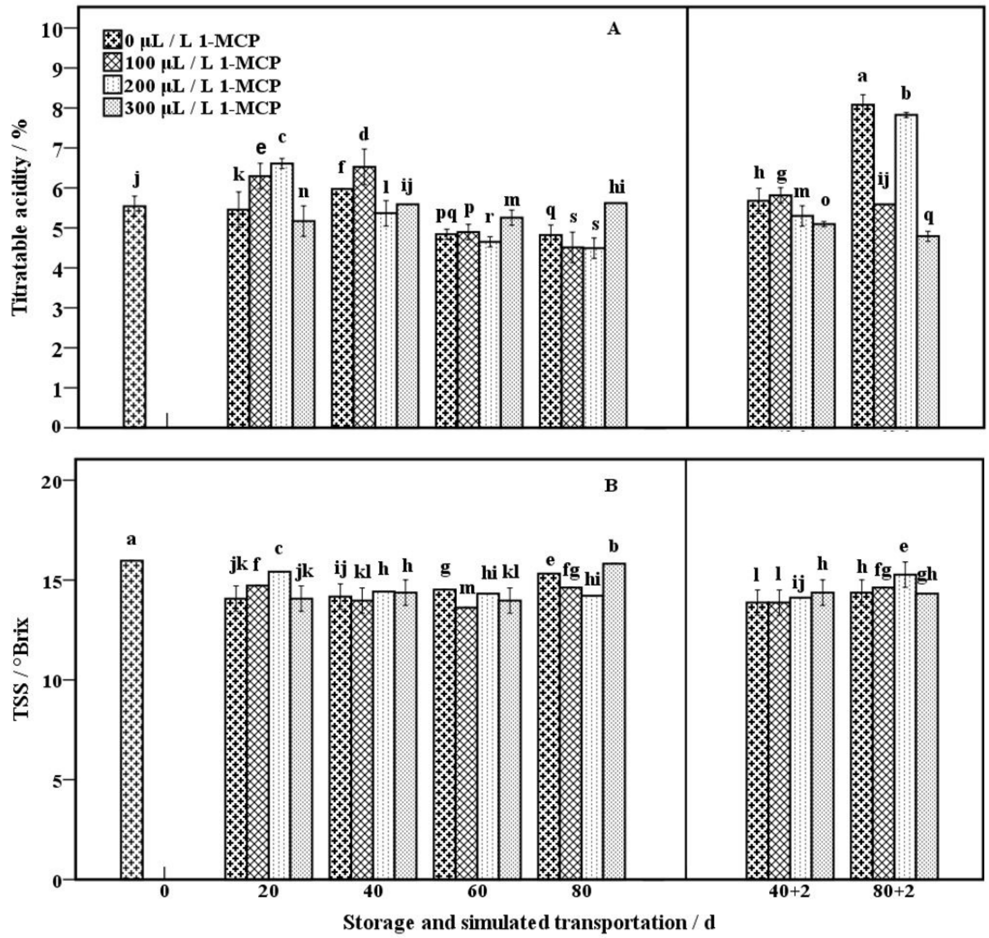

Figure 1. TA (A) and TSS (B) of blueberries during storage and simulated transportation. Different letters in each column represent significant differences between the ripe stage (*P < 0.05*). All measures were performed in three independent samples.

Table 2. Correlation analysis among parameters.

Indices	1 Firmness	2	3	4	5	6	7
2 Springiness	0.560**	1					
3 Cohesiveness	0.153	0.866**	1				
4 Gumminess	0.581**	0.396**	0.238	1			
5 Chewiness	0.556**	0.399**	0.255	0.986**	1		
6 Resilience	0.336**	0.860**	0.915**	0.402**	0.429**	1	
7 Total soluble solids	0.455**	0.907**	0.762**	0.259	0.257	0.671**	1
8 Titratable acidity	0.370**	0.592**	0.366**	0.178	0.199	0.292*	0.674**

*(P<0.05); **(P<0.01).

3.8 Correlation analysis

Table 2 displays the correlation among texture properties, TA and TSS during storage and transportation. These findings mirrored the trend reported for all the parameters (firmness, springiness, cohesiveness, gumminess, chewiness, resilience, TA and TSS). A positive correlation among the texture properties, TA and TSS was pointed out. The firmness was strongly correlated with springiness, gumminess, chewiness, resilience, TA and TSS. The springiness was strongly correlated with TSS, resilience, cohesiveness, TA, chewiness, and gumminess. The cohesiveness was strongly related to resilience, TA and TSS. The cohesiveness was strongly associated with resilience, TA and TSS. The gumminess was strongly correlated with chewiness and resilience. The chewiness was strongly correlated with resilience. The resilience was strongly correlated with TSS, weaker correlation with TA. Similar to our study, there was significant positive correlation among firmness, springiness, cohesiveness, gumminess, chewiness, resilience, TA and TSS, respectively (Li et al., 2011b; Tian et al., 2011; Li et al., 2013; Jia et al., 2014).

4. Conclusions

In this work, postharvest application of 0.3 μL L^{-1} 1-MCP effectively maintained the texture properties of blueberry during storage and simulated transportation. The results indicate that firmness, gumminess, and chewiness may play an important role in texture properties, and 1-MCP may delay the decrease of texture properties by maintaining the higher firmness, gumminess, and chewiness. As far as we know, this is the first reporting effects of 1-MCP on texture properties of blueberry during storage and simulated transportation. The results of this study suggest that 1-MCP combines with commercial polyethylene bags can effectively extend the storage period and maintain texture properties of blueberry.

Ethical statements

We do not have any conflict of interest. This study does not involve any human or animal testing.

Acknowledgements

The authors would like to thank the Blueberry industry special plan of Science and Technology Cooperation for Qiandongnan Prefecture of Guizhou Province, China (No. 201402), Collaborative Innovation Center for Fruit Processing, Storage, and Safety of Guizhou Province, China (No. [2013]06) and Scientific and Technological Innovation Team for Guizhou Fruit Processing and Storage, China (No. [2013]4028) for financial support.

References

Allan-Wojtas, P., Forney, F., Carbyn, E., & Nicholas, G. (2001). Microstructural indicators of quality-related characteristics of blueberries - an integrated approach. *Lebensmittel-Wissenschaft + Technologie*, 34(1), 23-32. http://dx.doi.org/10.1006/fstl.2000.0738.

Argenta, L. C., Vieira, M. J., & Scolaro, A. M. T. (2009). Conservação da qualidade de caqui 'Fuyu' em ambiente refrigerado pela combinação de 1-MCP e atmosfera modificada. *Revista Brasileira de Fruticultura*, 31(2), 323-333. http://dx.doi.org/10.1590/S0100-29452009000200006.

Chiabrando, V., & Giacalone, G. (2011). Shelf-life extension of highbush blueberry using 1-methylcyclopropene stored under air and controlled atmosphere. *Food Chemistry*, 126(4), 1812-1816. PMid:25213961. http://dx.doi.org/10.1016/j.foodchem.2010.12.032.

Dan, M., & Nesmith, S. (2011). Rabbiteye blueberry postharvest fruit quality and stimulation of ethylene production by 1-methylcyclopropene. *HortScience*, 46(9), 1278-1281.

Delong, J., Prange, R., & Bishop, C. (2003). The influence of 1-MCP on shelf-life quality of highbush blueberry. *HortScience*, 38(3), 417-418.

Guo, F., Wang, Y., Li, P., Sun, Y., Cao, J., & Luo, D. (2015). Effects of 1-methylcyclopropene treatments on texture properties of red pepper during post-harvest storage. *Food science*, 36(16), 272-277. In Chinese.

Jeong, J. (2004). 1-methylcyclopropene (1-MCP) for maintaining texture quality of fresh-cut tomato. *HortScience*, 39(6), 1359-1362.

Ji, S., Zhou, Q., Ma, C., & Cheng, S. (2014). Effect of 1-MCP treatment on quality changes of blueberry at room temperature. *Food Science*, 35(2), 322-327. In Chinese.

Jia, Y., Liu, C., Li, J., Zhang, P., Liu, L., & Chen, S. (2014). Effect of different treatment time of 1-MCP on texture of Fuji apple fruit at room temperature. *Science and Technology of Food Industry*, 35(23), 319-322. In Chinese.

Li, C., Luo, J., & MacLean, D. (2011a). A novel instrument to delineate varietal and harvest effects on blueberry fruit texture during storage. *Journal of the Science of Food and Agriculture*, 91(9), 1653-1658. PMid:21445891. http://dx.doi.org/10.1002/jsfa.4362.

Li, Z., Zhang, P., Zhang, K. M., & Ren, Z. H. (2011b). Effect of 1-methylcyclopropene combined with controlled freezing-point storage on texture of grape fruit. *Nongye Jixie Xuebao*, 42(7), 176-181. In Chinese.

Li, J., Lin, Y., Zhang, P., Qin, G., Li, B., & Tian, S. (2013). Effect of 1-methylcyclopropene treatment at different times postharvest on the texture of apple fruits. *Food Science*, 34(20), 277-281. In Chinese.

Liu, R., Wang, Y., Qin, G., & Tian, S. (2016). Molecular basis of 1-methylcyclopropene regulating organic acid metabolism in apple fruit during storage. *Postharvest Biology and Technology*, 117, 57-63. http://dx.doi.org/10.1016/j.postharvbio.2016.02.001.

Rizzolo, A., Grassi, M., & Vanoli, M. (2015). Influence of storage (time, temperature, atmosphere) on ripening, ethylene production and texture of 1-mcp treated 'abbéfétel' pears. *Postharvest Biology and Technology*, 109, 20-29. http://dx.doi.org/10.1016/j.postharvbio.2015.06.003.

Singh, V., Guizani, N., Al-Alawi, A., Claereboudt, M., & Rahman, M. S. (2013). Instrumental texture profile analysis (tpa) of date fruits as a function of its physico-chemical properties. *Industrial Crops and Products*, 50(10), 866-873. http://dx.doi.org/10.1016/j.indcrop.2013.08.039.

Tian, H., Zhang, P., Nong, Z., & Li, Z. (2011). Analysis on texture properties of treated grape fruit with 1-MCP based on TPA test. *Food &Machinery*, 27(3), 104-107. In Chinese.

Wang, X., Guan, J., Wang, X., & Liu, Y. (2013a). Effect of 1-MCP on flesh texture of 'Whangkeumbae' pear during ambient temperature storage. *Journal of Agricultural University of Hebei*, 36(2), 46-49. In Chinese.

Wang, Y., Cai, Q., An, L., Zhang, Y., Tian, Y., He, X., Liang, L., Wang, G., Chen, Y., & Li, J. (2013b). Multivariate analyses of the effect of 1-methylcyclopropene on fruit quality and reactive oxygen species in blueberry fruit. *Food Science*, 34(14), 340-345. In Chinese.

Wang, Y. S., Cai, Q. W., An, L., Liang, L. S., Wang, G. X., & Liu, Y. G. (2014). Multivariate analysis of the influence of 1-methylcyclopropene and chlorine dioxide on fruit quality of blueberry during low temperature storage. *Journal of Chinese Institute of Food Science and Technology*, 14(5), 253-258. In Chinese.

Wang, Y., Gao, J., Zhang, X., Wang, H., & Yang, S. (2015). Effects of 1-methylcyclopropene treatment on the blueberry fruit quality during cold storage. *Food Research and Development*, 36(10), 132-136. In Chinese.

Xie, B., Gu, Z., Wang, S., Zhuang, H., & Zeng, J. (2009). Effect of 1-MCP on texture properties of fresh fruit in storage shelf period of Zizyphus jujuba 'Zhongqiusucui'. In: Liu M. J. (Ed.), I International Jujube Symposium (pp. 499-504). Baoding, China: ISHS.

Xie, G., Tan, S., & Yu, L. (2015). Effect of cultivar on quality of the common bean during storage. *International Agricultural Engineering Journal*, 24(2), 69-78.

Xie, G., Wang, J., Xu, X., Wang, R., Zhou, X., & Liu, Z. (2016). Effect of different ripening stages on bioactive compounds and antioxidant capacity of wild Rosa laevigata Michx. *Food Science and Technology (Campinas)*, 36(3), 396-400. http://dx.doi.org/10.1590/1678-457X.00715.

Zheng, T., & Li, X. (2007). Primary Study on the Changes of Texture Properties of Tomato during fresh- keeping with 1- MCP. *Journal of Chinese Institute of Food Science and Technology*, 7(5), 75-78. In Chinese.