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Postharvest Quality of Nectarine *cv.* 'Venus' as Affected by Hot Water Dips and Length of Storage

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Abstract

The effect of hot water dip (48° C) duration (6 or 12 minutes) (HWD 48° C 6' and HWD 48° C 12') and length of storage at 0° C in normal atmosphere (two or four weeks) on chemical and sensory quality of nectarine (*Prunus persica* var. *nectarina cv.* 'Venus') was studied. After two weeks of storage, HWD-treated fruits had significantly lower weight loss and SSC compared to control. There was no significant difference between HWD 48 °C 6' and HWD 48 °C 12' – treated fruit. HWD 48 °C 12' - treated fruit maintained sensory quality after two weeks of storage. After four weeks of storage, control fruit received higher scores compared to HWD – treated fruit for all traits, except for aroma which was still higher for HWD 48 °C 12' - treated fruit. Duration of hot water dip is significant factor for maintaining postharvest quality of nectarine fruit.

Key words: nectarine, heat treatment, hot water dip, exposure, storage

Introduction

Nectarine is a climacteric fruit which softens and deteriorates quickly after harvest. The main method for controlling such negative changes is cold storage (Wang & Feng, 2006; Lurie & Crisosto, 2005) in controlled atmosphere with high CO_2 concentration (Brackmann et al., 2007; Retamales et al., 1992; Levin et al., 1995; Zhou et al., 2000). However, such storage can affect some aroma compounds (Cano-Salazar et al., 2013).

Another problem of nectarine cold storage is occurrence of chilling injury in prolonged exposure to low temperature (Peace et al., 2006). Chilling injury is a complex phenomenon characterised by developing off-flavour, changed flesh consistency and occurrence of internal browning and flesh reddening (Crisosto et al., 1999; Lurie & Crisosto, 2005; Crisosto et al., 2008.) which leads to lower consumer acceptance of this fruit (Zhou et al., 2000). Although genetically controlled, a

combination of temperature and exposure is the main cause of injury occurrence (Crisosto et al., 1999). Most cultivars develop chilling injury symptoms after two to three weeks of storage below 8° C (Lill et al., 1989).

Fruits stored between 2.2 °C and 7.6 °C are more prone to chilling injury than those stored at 0 °C or lower (Crisosto et al., 1999.). Storage at 0 °C maintains firmness, juiciness, decreases weight loss and chilling injury occurrence up to four weeks than storage at 5 and 8° C (Lee et al., 2006; Shu Shang et al., 2003). Delayed storage also helps in preventing development of this injury (Zhou et al., 2000).

Postharvest decay causes high fruit losses (Lurie et al., 1995; Margosan et al., 1997; Singh & Mandal, 2006). Fruits that suffered from chilling injury are more susceptible to decay (Çelik et al., 2006). *Botrytis cinerea, Penicillium expansum* and *Rhizopus stolonifer* are main causal agents of decay of nectarines after harvest (Fan & Tian, 2000; Karabulut et al., 2002; Karabulut & Baykal, 2004). Lurie et al. (1995) and Margosan et al., (1997) reported that the most frequent fungal pathogens of nectarines are *Monilinia fructicola* and *Penicillium expansum*. In the Republic of Croatia, the main fungal pathogen is *M. laxa* whereas *M. fructigena* and *R. stolonifer* are less frequent (Jemrić et al., 2009). These pathogens can cause postharvest loss as high as 80 % (Jemrić et al., 2009). In EU countries postharvest use of fungicides is prohibited, and alternative technologies for decay control are needed.

Heat treatment is environmentally friendly and effective method for controlling postharvest loss of fruit and vegetables (Lu et al., 2007). There are two main methods for applying heat to fruit: hot air treatment (HAT) and hot water dip (HWD). HAT cannot effectively control postharvest decay on some nectarine cultivars (Fruk et al., 2009; Murray et al., 2007), whilst on others HWD can increase decay caused by *P. expansum* (Fruk et al., 2012). HWD at 48°C for 12 min and 6 min can significantly reduce occurrence of *Monilinia laxa* on peach and nectarine during storage (Jemric et al., 2011). Çandir et al. (2009) reported lower postharvest weight loss and decay incidence in nectarine *cv.* 'Big Top' treated with HWD at 45° C for 2 min. Karabulut et al (2010) showed efficacy of HWD in controlling decay incidence on peaches, nectarines, and plums by brief immersion of fruits into hot water at 60° C for 60 s. Therefore, optimising the temperature range and duration to improve the uniformity in effectiveness of heat treatment, and conducting research into a protocol for the adoption of different heat treatments as part of the postharvest chain is the main task for future research (Lu et al., 2007). Singh & Mangal (2006) controlled *R. stolonifer* on peach by combining HWD at 50° C for 3 min and bioagent *Debaryomyces hansenii*, but decay incidence was over 50 % after 30 days of storage, even in treated fruit.

Nectarine *cv.* 'Venus' stored at 0° C for 14 and 42 days has been less accepted by consumers, indicating its decreased storage potential (Infante et al., 2008). Therefore, the aim of this study was to evaluate the effect of HWD duration and length of storage on quality and sensory attributes of nectarine *cv.* 'Venus'.

Materials and methods

Nectarine fruit 'Venus' was obtained from the commercial orchard in the area of Ravni Kotari near Zadar. Fruits were harvested at optimal maturity stage for storage. Fruits with no visual symptoms of decay were selected and divided into three lots of 72 fruits each.

One lot was dipped into hot water at 48 °C for 6 min (HWD 48 °C 6'), another lot was dipped into hot water at 48 °C for 12 min (HWD 48 °C 12'**)** and third lot was used as untreated control.

After the treatments, fruits were stored in air at 0 °C for two and four weeks. After storage, fruits were transferred to room temperature for 5 days shelf life (SL). Standard quality measurements were conducted on three replicates of 24 fruits each for each treatment. Fruit weight was measured before treatment, after storage and after SL to determine weight loss.

Fruit weight measurements were conducted with analytical scale (Mettler P1210) at two decimals in grams. Soluble solid concentration (SSC) was measured with hand refractometer (Carl Zeiss, Germany). Total acids (TA) were measured by titrimetric method with 0.1 M NaOH on 5 ml of fruit juice and calculated as equivalent of malic acid. Maturity index was calculated as SSC : TA ratio.

A sensory analysis was performed according to Miller et al. (2005). Firmness, texture, juiciness, sugar : acidity ratio, aroma, taste and general impression were scored using a bipolar 5-point (1 to 5) hedonic scale. On the scale the 1-unit intervals were considered: dislike, dislike slightly, like, like very much, and like exceptionally.

The effects of treatments were analysed by ANOVA and significance of differences among means was tested with the LSD test at $P \leq 0.05$ using the SAS Statistical package ver. 9.2 (SAS Institute, Cary, USA).

Results and discussion

Weight loss and titratable acids (TA) have been significantly lower after two weeks of storage, and the treatment was a significant factor only for weight loss (Table 1). Soluble solids concentration (SSC) and TA ratio (SSC : TA) were significantly lower after four weeks of storage.

After two weeks of storage, HWD-treated fruits had significantly lower weight loss and SSC compared to control. There was no significant difference between HWD 48° C 6' and HWD 48 °C 12' – treated fruits (Table 2).

After four weeks of storage there was no significant difference between control and HWD-treated fruits as well as between HWD 48 °C 6' and HWD 48 °C 12' – treated fruits (Table 2).

Tab. 1. ANOVA – table for quality parameters of hot water dipped fruit of nectarine *cv.* 'Venus' and stored for two or four weeks at 0° C plus 5 days of shelf life (SL) at room temperature (mean ± SD)

	Storage weight loss *Gubitak na težini zbog skladištenja* (%)	Shelf life weight loss *Gubitak na težini zbog roka trajanja nakon skladištenja* (%)	Total weight loss *Ukupni gubitak na težini* (%)	SSC (%)	TA (%)	SSC : TA
Storage / *Skladištenje* (S)	***	***	***	n.s.	***	***
Treatment / *Tretman* (T)	*	***	**	n.s.	n.s.	n.s.
S x T	*	n.s.	*	n.s.	n.s.	n.s.
Treatment / *Tretman*						
Control Kontrola	5.24±2.05[x]	3.66±1.84 a	8.92±3.56[x]	9.46±0.80	0.79±0.15a	12.57±2.95
HWD 48 °C 6'	4.77±2.22	3.53±2.35 a	8.34±4.20	9.06±0.72	0.76±0.16a	12.56±3.03
HWD 48 °C 12'	4.19±1.88	2.98±1.76 b	7.93±3.41	9.21±0.82	0.77±0.20a	12.49±2.96
Storage / *Skladištenje*						
2WK + 5d SL	3.69±1.43	2.03±1.33	5.66±2.09	9.38±0.71	0.69±0.13	14.04±2.80
4WK + 5d SL	6.29±1.74	4.64±1.69	10.93±3.11	9.11±0.84	0.83±0.17	11.35±2.50

A sensory analysis (Figs. 1 and 2) showed significant effect of storage time as well as ability of HWD 48 °C 12' - treated fruit to maintain its quality, but only after two weeks of storage (Fig. 1). These fruits achieved better scores for firmness, texture, sugar : acidity ratio, aroma, taste and general impression. HWD 48 °C 6' – treated fruit received lower score, but still higher than control for following traits: sugar : acidity ratio, aroma, taste and general impression. Control fruits received lowest scores for juiciness, sugar : acidity ratio, aroma, taste and general impression.

However, after four weeks of storage, control fruits received higher scores compared to HWD – treated fruits for all traits, except for aroma which was still higher for HWD 48 °C 12' - treated fruits (Fig. 2).

Tab. 2. Quality of hot water dipped nectarine fruit *cv.* 'Venus' after storage for two or four weeks at 0° C plus 5 days of shelf life (SL) at room temperature (mean ± SD)

Treatment *Tretman*	Storage weight loss *Gubitak na težini zbog skladištenja* (%)	Shelf life weight loss *Gubitak na težini zbog roka trajanja nakon skladištenja* (%)	Total weight loss *Ukupni gubitak na težini* (%)	SSC (%)	TA (%)	SSC : TA
2 WK+ 5 d SL						
Control Kontrola	4.30±1.85a	2.34±1.43a	6.58±2.64a	9.81±0.80a	0.72±0.14a	14.13±2.69a
HWD 48 °C 6'	3.19±1.16b	1.96±1.25b	5.01±1.47b	9.21±0.52b	0.70±0.15a	13.70±3.22a
HWD 48 °C 12'	3.57±0.91b	1.80±1.24b	5.36±1.61b	9.17±0.67b	0.63±0.08a	14.49±2.39a
4 WK + 5 d SL						
Control Kontrol	6.22±1.77a	4.92±1.18a	11.14±2.82a	9.15±0.67a	0.84±0.16a	11.33±2.60a
HWD 48 °C 6'	6.41±1.84a	4.97±2.20a	11.32±3.58a	8.92±0.87a	0.81±0.16a	11.43±2.43a
HWD 48 °C 12'	6.24±1.63a	4.08±1.43b	10.35±2.84a	9.24±0.97a	0.86±0.21a	11.29±2.65a

Note: means followed by the same letter are not significant according to LSD test at P≤0.05
Napomena: srednje vrijednosti iza kojih slijedi isto slovo nisu značajne prema testu LSD pri P≤0.05

Heat treatments significantly decreased weight loss, but only after two weeks of storage. This confirms previous studies which reported low storage potential of nectarine *cv.* 'Venus' (Infante et al., 2008). Many other studies (Çandir et al., 2008; Fruk et al., 2012; Jemric et al., 2012; Stubljar et al, 2012) also showed that HWD treated fruits have lower weight loss compared to control. Çandir et al. (2008) found that increasing duration of HWD from two to three minutes also increases weight loss. This effect was not observed in our study. Zhou et al. (2002) reported increased weight loss of peach fruit when subjected to HWD at 37, 40 and 43° C for extremely long exposure ranging from 0.5 to 3 h. Such long treatment even caused heat damage and cannot be recommended for postharvest practices.

TA and SSC : TA ratio did not change significantly as the result of HWD. This is in accordance with other studies (Çandir et al., 2008; Fruk et al., 2012; Stubljar et al., 2012; Singh & Mangal, 2006). Jemric et al. (2011) found that HWD 48 °C 12' can decrease TA and SSC : TA ratio on nectarine 'Venus', but not on peach 'Roig'. Therefore, seasonal and genetic factors have strong influence on the effect of heat treatments (Crisosto et al., 1997; Crisosto et al., 2008). Persistence of TA in HWD - treated fruit is very important since organic acids are important factors of fruit sensory quality (Harker et al., 2002).

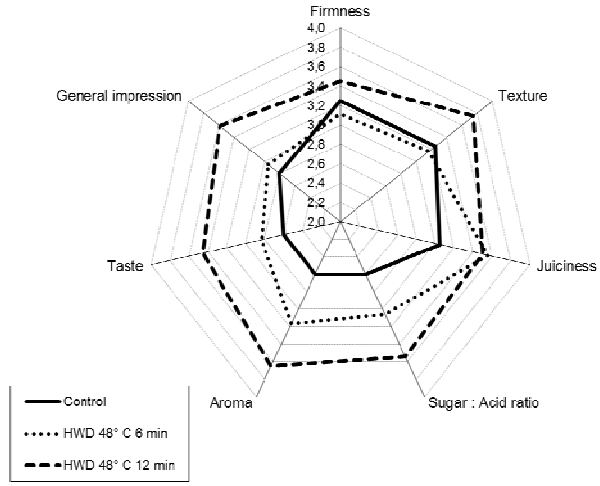

Fig. 1. Sensory quality of hot water dipped nectarine fruit *cv.* 'Venus' after storage for two weeks at 0° C plus 5 days of shelf life (SL) at room temperature.
Senzorni kvalitet plodova nektarine sorte "Venus" tretiranih vrelom vodom nakon skladištenja na temperaturi 0° C u trajanju od dvije sedmice plus rok trajanja od 5 dana na sobnoj temperaturi.

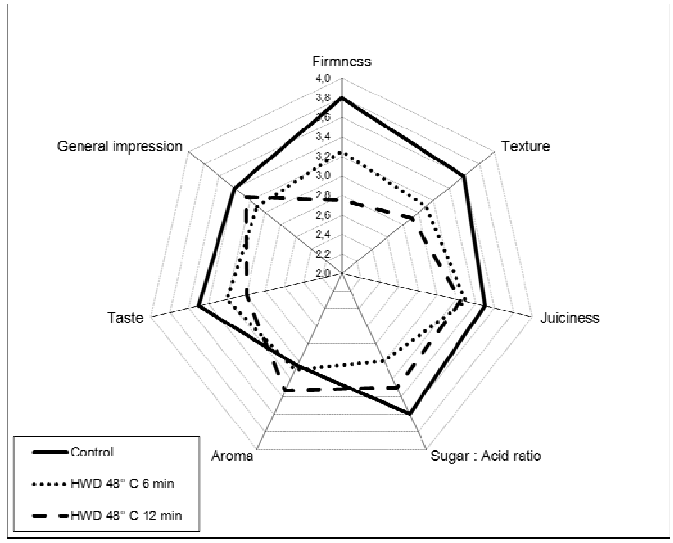

Fig. 2. Sensory quality of hot water dipped nectarine fruit *cv.* 'Venus' after storage for four weeks at 0° C plus 5 days of shelf life (SL) at room temperature.
Senzorni kvalitet plodova nektarine sorte "Venus" tretiranih vrelom vodom nakon skladištenja na temperaturi 0° C u trajanju od četiri sedmice plus rok trajanja od 5 dana na sobnoj temperaturi.

Significantly higher SSC found in control fruit after two weeks of storage is a result of higher weight loss which caused soluble solids to concentrate within the fruit. The cited studies did not report increase of SSC in HWD-treated fruit, but Mandal et al. (2007) also reported increased SSC in stored peaches after HWD at 50°C for 3 minutes combined with *D. hansenii*. Contrary to the cited study, Karabulut & Baykal (2004) found lower SSC in peaches treated by HWD at 55°C for 10 sec. It can be concluded that both temperature and duration of heat treatment are important factors that need to be carefully balanced to achieve positive effect on postharvest quality of fruit.

Sensory quality was better in HWD 48 °C 12' - treated fruits after two weeks of storage compared to both control and HWD 48 °C 6' - treated fruits. After four weeks, only aroma was scored better in HWD 48 °C 12' - treated fruit. To the best of our knowledge, we found no similar studies on peach or nectarine to discuss the sensory quality of HWD treated fruit.

Conclusion

It can be concluded that HWD 48 °C 12' is a promising heat treatment for maintaining postharvest quality of nectarine *cv.* 'Venus' for two weeks. However, further studies must include its combination with CA storage and other treatments to extend storage life for longer period.

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Kvalitet nektarine *cv.* 'Venus' nakon berbe i uticaj tretmana vrelom vodom i dužine skladištenja

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Sažetak

Ispitivan je uticaj umakanja u vrelu vodu (48° C) u trajanju od 6 ili 12 minuta (HWD 48° C 6' i HWD 48° C 12') i dužine skladištenja na 0° C u normalnoj atmosferi (dvije ili četiri) na hemijski i senzorni kvalitet nektarine (Prunus persica var. nectarina *cv.* 'Venus'). Nakon dvije sedmice skladištenja, voće tretirano HWD je znatno manje izgubilo na težini i imalo niži SSC u poređenju sa kontrolnom grupom plodova. Nije bilo veće razlike između HWD 48 °C 6' i HWD 48 °C 12'. Voće tretirano HWD 48 °C 12' je zadržalo senzorni kvalitet nakon dvije sedmice skladištenja. Nakon četiri sedmice skladištenja, kontrolni plodovi su dobili više ocjene u odnosu na voće tretirano HWD po pitanju svih osobina osim arome koje su još uvijek bile veće za voće tretirano HWD 48 °C 12'. Trajanje umakanja u vreloj vodi je bitan faktor za održavanje kvalitete plodova nektarine nakon berbe.

Ključne riječi: nektarina, toplinski tretman, umakanje u vrelu vodu, izlaganje, skladištenje.

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