Hot Water Treatment of Selected Organic Apple and Pear Cultivars

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Abstract

As one of several alternatives, organic fruit may be hot-water dipped prior to long-term storage in order to reduce postharvest decay. This method has been tested at Agroscope's Institute of Food Sciences during 3 years with selected apple ('Arlet', 'Golden Delicious', 'Otava', 'Topaz') and pear ('Kaiser Alexander', 'Uta') cultivars originating from organic, low-residue IP (integrated production) and IP orchards. Hot water treatment achieved a 2- to 10- fold reduction of the spoilage level during long-term CA-storage compared to non-treated organic apple and pear fruit. However, the efficacy of the treatment and the way it was carried out was highly dependent on the cultivar considered. The apple cultivar 'Arlet' did not need any hot water treatment, because this cultivar was hardly susceptible to decay. The other apple and pear cultivars considered in the trials required a treatment when produced under organic conditions. Based on the temperature sensitivity of the fruit with regard to temperature injuries, the threshold temperatures of the hot water treatment were for apples in the range of 50 to 52°C (duration 150 s) and for pears at a temperature of 49°C (duration 180 s).

INTRODUCTION

It is believed that apples and pears produced under organic conditions are more susceptible to decay during storage than fruit produced under integrated production (IP) conditions, because they cannot be treated with synthetic pesticides before harvest. Some pesticides have a long-term effect against spoilage during storage. The most important reason for rot of organic apples is the bitter rot (Mayr et al., 2008). The rate of spoilage during storage can amount up to 30-50% and depends on origin of fruit, maturity stage, rain fall during cultivation and harvest, orchard hygiene and finally on the cultivar itself. Losses during storage are not only undesirable because of loss of fruit, but also because costs for production and storage have been expended without any recompensation.

As one of several alternatives, organic fruit may be hot-water dipped prior to long-term storage. In practice, a high percentage of organic pome fruit cultivated in Switzerland is hot-water dipped prior to storage. The effectivity of this method has been demonstrated in some experiments (Trierweiler, 2012). Recent study (Maxin et al., 2012) showed that the effect of the method may not only be explained by the heat inactivation of postharvest pathogens, but also by the heat-induced formation of substances in the fruit which may reduce the growth of microorganisms (induced resistance). Even if the hot-water treatment is well established in Swiss practice, it is often believed that the method may induce fruit injuries and reduce fruit quality. Furthermore, various apple and pear cultivars seem to react in different ways on the hot-water treatment with regard to fruit rot and injuries. The objective of this work was therefore to test the effectiveness of hot-water treatment for some selected, organically grown apple and pear cultivars, and to evaluate simultaneously the side effects on physiology and quality of fruit.

MATERIALS AND METHODS

Fruit Material

Over three years (2009-2011), selected pome fruit cultivars (apples: 'Topaz', 'Ariane', 'Otava', 'Golden Delicious'; pears: 'Kaiser Alexander', 'Uta') where hot-water dipped under conditions as explained in Table 1. Apple cultivars originated from the same

Agroscope orchard and were grown under integrated production (IP) conditions, low-residue integrated conditions (LR IP), organic conditions (BIO) and without any treatment (control). For IP the usual pesticides against storage diseases were applied (fungicides Captan and Flint) and for BIO the products Myco-Sin, sulfur and Armicarb. For the LR IP variant, the application of synthetic pesticides was reduced in order to obtain minimal residues on the fruit: after bloom, trees were treated with a synthetic fungicide (Slick) and then further treated as for BIO variant with Myco-Sin, sulfur and Armicarb. The control variant without any treatment was just used in order to evaluate the effectiveness of the treatments. The pears used in the trials originated from a commercial orchard in the east of Switzerland (Bad Ragaz). Fruit were cultivated under organic, certified conditions in this orchard.

Hot Water Treatment and Storage Conditions

Hot water treatment was applied by dipping boxes with about 12 kg of fruit in a hot water bath kept at a fixed temperature during 150 s (see Table 1). Due to the high volume of the water bath, water temperature remained constant during the treatment. The treatment was applied 2-3 days after harvest. Apples and pears were stored at 1°C in regular atmosphere (RA) for 5 and 4.5 months, respectively and in controlled atmosphere (CA) for 7 and 5 months, respectively. CA-conditions were fixed at 1.5% for CO_2 and O_2 for apples, and at 1.5% CO_2 and 2.0% O_2 for pears. After removal from storage, fruit rot was determined by counting the number of decayed fruit.

Quality Measurements

Fruit quality was determined at the time of harvest and at the end of the storage period and the shelf life respectively by measuring fruit firmness, total soluble solids (TSS), titratable acidity and fruit weight with a Pimprenelle instrument (SETOP, Cavaillon, France). Four replicates with 5 fruit each removed from storage were analyzed immediately and four replicates with 5 fruit each were stored for a subsequent shelf life period at 20°C for 7 days in normal atmosphere before being analyzed. Statistical analyses were performed using XLStat Pro V2011.204 (Addinsoft, Andernach, Germany). All experiments were performed in replicates as mentioned above and results are expressed as mean ± standard deviation. Significant differences between means were determined by analysis of variance (ANOVA) using Tukey's/Duncan's post hoc tests for pairwise comparisons of means ($p<0.05$).

RESULTS

Fruit Rot as Influenced by Production System

As illustrated in Tables 2 and 3, fruit grown under organic conditions exhibited the highest percentage of fruit rot, followed by fruit originating from IP low-residue production. Conventional IP fruit was only affected by minor fruit rot or not at all. A result, which may be well explained by the fact, that IP fruit are treated before harvest with synthetic fungicides which have a long-term effect on the growth of postharvest pathogens even during storage, whereas organic fruit cannot be treated with synthetic fungicides.

Fruit Rot as Influenced by Cultivar

Fruit rot was affected by the cultivar, 'Topaz' being the most susceptible cultivar and 'Ariane' the most resistant to fruit rot. The difference in resistance to fruit rot may be illustrated by the results for control fruit without any treatment (mean of the percentage of rotted fruit over 3 years under CA-conditions): For 'Ariane' the percentage of rotted fruit was at 2%, whereas fruit rot was higher for 'Golden Delicious' (4%), 'Otava' (10%) and 'Topaz' (28%). This finding corresponds to the experience in practice, where 'Topaz' is in general the most susceptible cultivar to fruit rot. For organic fruit, IP LR fruit and IP fruit, the corresponding values over 3 years were 2.3, 2.4 and 0.7% for 'Ariane', 2.7, 0.9

and 1.0% for ‘Golden Delicious’, 10, 9.2 and 2.2% for ‘Otava’ and 12.6, 16.7, 2.8% for ‘Topaz’.

Hot Water Treatment of Apples

Hot water treatment of IP LR and BIO fruit reduced the incidence of fruit rot for all cultivars tested. Compared to non-treated fruit, the reduction was in the range of 20 to 90%, depending on the cultivar. The reduction of fruit rot was much higher for the susceptible cultivars ‘Otava’ and ‘Topaz’ than for the more resistant cultivars ‘Golden Delicious’ and ‘Ariane’. The efficacy of hot water treatment was not influenced by the harvest date (data not shown). However, the treatment caused in some cases fruit injuries, mostly skin browning, as compared with non-treated fruit (Tables 2 and 3). The incidence of injuries was dependent on the cultivar and varied from year to year. Red-skinned apples such as ‘Topaz’ could be treated effectively at a temperature of 52°C during 2½ min without noteworthy injuries. Contrary to ‘Topaz’, the cultivar ‘Golden Delicious’ suffered from injuries such as skin browning at a temperature of treatment of 50°C during 2½ min. Additionally, ‘Golden Delicious’ from second harvest date was more susceptible to skin browning than fruit from the first harvest date. As illustrated by the incidence of fruit injuries for the cultivar ‘Topaz’, injuries varied from year to year, showing that climatic conditions might have an influence on susceptibility of fruit.

Hot Water Treatment of Pears

As illustrated in Table 4, the hot water treatment was effective also for pears, since fruit rot during storage for treated fruit was reduced by up to 100% compared to non-treated fruit. Hot-water treatment caused in the season 2011/2012 fruit injuries in form of skin browning, different to the previous year, where no injuries could be detected. Thus as for apples, fruit injuries varied also for pears from year to year. Temperatures of less than 48°C were not effective with regard to reduction of fruit rot, temperatures of more than 50°C consistently caused distinct heat injuries. It is thus very important to be in the temperature range of 49-50°C for the hot-water treatment of pears in order to guarantee an effective treatment without fruit injuries.

Fruit Quality

Another important question is, whether hot water treatment has a negative impact on fruit quality as determined by fruit firmness, acidity and sugar content. For all trials and cultivars tested, no significant difference could be detected between treated and non-treated fruit. Table 5 illustrates, as an example, the fruit quality after removal of apples from regular storage and after subsequent shelf life for the storage season 2010-2011. In most cases, there was no significant difference between the hot water and the control variant, independent from the production method (LR IP or Bio). In some few cases, a significant difference could be detected between the two variants. However, none of the two variants was overall better than the other. The same pattern as shown in Table 5 could be identified for all CA- and RA-stored apple and pear cultivars tested in this study.

DISCUSSION

Fruit Rot as Influenced by Cultivar

Independent from the production method, fruit rot was strongly dependent on the cultivar. In Switzerland, most of the companies storing organic apples, treat systematically all incoming apple cultivars by hot water dipping. Based on our results, resistant cultivars such as ‘Ariane’ could be put in store without any treatment. This would be an energy-saving approach, furthermore potential heat induced injuries could be avoided.

Hot Water Treatment

Overall, hot water treatment achieved a 2- to 10- fold reduction of the spoilage level during long-term CA-storage compared to non-treated apple and pear fruit. This was true for organic fruit as well as for fruit grown under IP low-residue conditions (LR IP). Based on the temperature sensitivity of the fruit with regard to temperature injuries, the threshold temperatures of the hot water treatment had to be adapted for apples in the range of 50 to 52°C (duration 150 s) and for pears at a temperature of 49°C (duration 180 s).

Fruit Damage

Injuries due to hot water treatment varied from year to year. The most encountered injury was skin browning. The extent of injuries was strongly influenced by the cultivar, 'Otava' being the most susceptible (up to 88%) and 'Topaz' with an acceptable level of up to 2%. Year-to-year variations of temperature sensitivity make the hot water treatment somehow unpredictable with regard to temperature injury. For pears, the efficacy of the treatment is limited, because the temperature of 49°C is at the lower limit of being effective against microorganisms. Apart of the method of hot water treatment itself, the moment of treatment after harvest seems to have an influence on the efficacy: the later the treatment, the less is the efficacy. A treatment just after harvest seems to be the best approach (Trierweiler, 2012).

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Tables

Table 1. Overview of hot-water trials (hot water dipping apples: 150 s, pears 180 s) (harvest date [HD] 1 = commercial harvest date, 2 = about 7-10 days after commercial harvest).

	Temperature (°C)					
	2009/2010		2010/2011		2011/2012	
	HD1	HD2	HD1	HD2	HD1	HD2
Ariane	-	-	52	-	-	-
Golden Delicious	-	-	52	-	50	50
Otava	-	-	52	-	-	-
Topaz	52	52	52	-	52	52
Kaiser Alexander	-	-	49	-	49	-
Uta	-	-	49	-	49	-

Table 2. Fruit rot and injuries after 5 months of storage in regular atmosphere (apples harvested at commercial harvest date (in italic: injuries due to heat treatment HT).

Cultivar	Cultivation method	Apple scab (%)			Total fruit rot (%)			Hot water injuries (%)		
		2010	2011	2012	2010	2011	2012	2010	2011	2012
Ariane	Bio	0.0	0.0	0.0	1.4	1.3	2.8	-	0.0	-
	Bio HT	-	0.0	-	-	0.6	-	-	*9.9*	-
	IP-LR	0.0	0.0	0.0	0.6	2.7	4.7	-	0.0	-
	IP-LR HT	-	0.0	-	-	1.1	-	-	*7.8*	-
	IP	0.0	0.0	0.0	0.7	0.3	0.2	-	-	-
Golden Delicious	Bio	1.3	4.3	54.0	5.0	10.0	2.4	-	0.0	0.0
	Bio HT	-	3.2	46.9	-	1.7	0.9	-	*0.0*	*0.0*
	IP-LR	0.4	4.0	8.5	0.6	9.9	7.7	-	0.0	0.0
	IP-LR HT	-	1.2	4.5	-	0.9	0.7	-	*0.0*	*0.0*
	IP	0.0	0.3	0.0	0.5	1.9	2.0	-	-	-
Otava	Bio	0.0	0.0	0.0	7.3	43.8	32.8	-	0.0	-
	Bio HT	-	0.0	-	-	6.3	-	-	*88.2*	-
	IP-LR	0.0	0.0	0.0	3.7	68.9	30.0	-	0.0	-
	IP-LR HT	-	0.0	-	-	9.8	-	-	*76.8*	-
	IP	0.0	0.0	0.0	0.6	15.0	4.8	-	-	-
Topaz	Bio	0.0	0.0	0.0	26.9	40.3	74.0	0.0	0.0	0.0
	Bio HT	0.0	0.0	0.0	0.7	4.6	6.7	*0.0*	*2.1*	*0.0*
	IP-LR	0.0	0.0	0.0	1.8	53.0	61.1	0.0	0.0	0.0
	IP-LR HT	0.0	0.0	0.0	1.5	5.1	6.4	*0.0*	*2.1*	*0.0*
	IP	0.0	0.0	0.0	3.3	4.9	12.7	-	-	-

Table 3. Fruit rot and injuries after 7 months of storage in controlled atmosphere (apples harvested at commercial harvest date (in italic: injuries due to heat treatment HT).

Cultivar	Cultivation method	Apple scab (%)			Total fruit rot (%)			Hot water injuries (%)		
		2010	2011	2012	2010	2011	2012	2010	2011	2012
Ariane	Bio	0.0	0.0	0.0	1.4	3.0	2.6	-	0.0	-
	Bio HT	-	0.0	-	-	1.1	-	-	*0.0*	-
	IP-LR	0.0	0.0	0.0	0.0	1.4	5.7	-	0.0	-
	IP-LR HT	-	0.0	-	-	1.1	-	-	*0.0*	-
	IP	0.0	0.0	0.0	0.0	0.0	2.2	-	-	-
Golden Delicious	Bio	0.8	10.1	53.8	3.8	2.2	2.2	-	0.0	-
	Bio HT	-	3.5	-	-	1.3	-	-	*6.4*	-
	IP-LR	1.0	5.3	11.5	0.7	0.9	1.2	-	0.0	-
	IP-LR HT	-	1.6	-	-	1.0	-	-	*11.9*	-
	IP	0.0	1.0	0.0	0.9	0.9	1.3	-	-	-
Otava	Bio	0.0	0.0	0.0	4.9	21.6	4.2	-	0.0	-
	Bio HT	-	0.0	-	-	9.9	-	-	*76.1*	-
	IP-LR	0.0	0.0	0.0	1.2	21.6	4.9	-	0.0	-
	IP-LR HT	-	0.0	-	-	7.8	-	-	*52.7*	-
	IP	0.0	0.0	0.0	0.5	5.1	1.2	-	-	-
Topaz	Bio	0.0	0.0	0.0	19.3	14.6	12.6	0.0	0.0	-
	Bio HT	0.0	0.0	-	0.0	2.8	-	*0.0*	*0.3*	-
	IP-LR	0.0	0.0	0.0	27.2	15.7	7.2	0.0	0.0	-
	IP-LR HT	0.0	0.0	-	4.8	4.1	-	*0.0*	*0.4*	-
	IP	0.0	0.0	0.0	4.6	2.3	1.6	-	-	-

Table 4. Fruit rot and injuries of selected pear cultivars stored in regular atmosphere (RA) and controlled atmosphere (CA) during 4.5 and 5 months respectively. (in italic: disorders due to heat treatment HT).

Cultivar	Postharvest treatment	Storage method							
		NA				CA			
		Fruit rot (%)		Various disorders (%)		Fruit rot (%)		Various disorders (%)	
		2010	2011	2010	2011	2010	2011	2010	2011
Kaiser Alexander	None	2.99	0.00	1.49	5.80	9.10	5.54	0.00	0.00
	Hot-water	0.00	0.00	*0.00*	*39.96*	3.06	9.89	*0.00*	*80.00*
Uta	none	1.75	1.05	0.00	0.00	4.57	4.87	0.00	0.00
	Hot-water	3.22	0.00	*1.05*	*13.95*	0.00	1.04	*0.00*	*63.00*

Table 5. Influence of hot-water treatment (HT) on fruit quality after storage in regular atmosphere at 1°C during 5 months and after subsequent shelf life (7 days at 20°C) (storage season 2010-2011).

		Organic production				Low residue integrated production			
		After storage		After Shelf life		After storage		After shelf life	
		HT	Control	HT	Control	HT	Control	HT	Control
Ariane	Firmness (kg/cm^2)	7.58b[1]	8.24a	7.09b	7.80a	6.86b	7.42a	6.81b	7.26a
	TSS (°Brix)	13.60a	13.39a	13.36a	13.10a	12.22a	12.17a	12.35a	12.21a
	Acidity (g malic acid/L)	5.91a	5.93a	4.66a	4.76a	5.06a	4.92a	4.23a	4.16a
Golden	Firmness (kg/cm^2)	6.16a	5.82a	5.99a	5.83a	5.13a	5.10a	5.05a	5.16a
	TSS (°Brix)	16.14a	15.50a	15.51a	15.27a	13.99a	13.68a	13.96a	14.08a
	Acidity (g malic acid/L)	4.49a	4.65a	3.83a	3.75a	3.92a	4.08a	3.23b	3.68a
Otava	Firmness (kg/cm^2)	6.01a	5.70a	5.90a	6.14a	5.80a	6.06a	5.97a	5.87a
	TSS (°Brix)	14.38a	13.33b	14.96a	13.64b	13.47a	13.79a	14.13a	13.72a
	Acidity (g malic acid/L)	7.66a	6.67b	6.79a	5.97b	7.05a	7.29a	6.61a	6.22a
Topaz	Firmness (kg/cm^2)	5.72a	5.77a	5.73a	5.85a	5.60a	5.47a	5.72a	5.36b
	TSS (°Brix)	13.44a	13.57a	13.35a	13.57a	12.86a	12.54b	12.93a	12.25b
	Acidity (g malic acid/L)	6.10a	6.08a	5.22a	5.38a	5.88a	5.64a	5.34a	4.72b

[1] Values followed by different characters differ significantly at $\alpha=0.05$ (HT compared to control).