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Brine Quality of Gibberellic Acid-treated 'Napoleon' Sweet Cherries

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Abstract. **Gibberellic acid-treated 'Napoleon' sweet cherry *(Prunus avium* L.) fruit were firmer but lost more weight during brining than nontreated fruit. GA_3 treatment delayed fruit softening, thereby extending the harvest period. Mean fruit weight was increased by GA_3 only in fruit harvested at a more mature state. GA_3 delayed soluble solids accumulation in one of two years. In one orchard district, solution pockets were less frequent in GA_3-treated fruit in 1988 and in late-harvested GA_3-treated fruit in 1989. GA_3 treatment did not alter the incidence of fruit with solution pockets in a second district in 1988 and increased levels of solution pockets in fruit harvested later in 1989. Incidence of fruit with solution pockets increased as maturity progressed in nontreated fruit in both years and both districts. Chemical name used: gibberellic acid (GA_3).**

Foliar applications of GA, are used commercially in the Pacific Northwest fresh sweet cherry industry to delay fruit ripening (Looney and Lidster, 1980; Proebsting et al., 1973) and increase size and firmness (Facteau et al., 1985; Looney and Lidster, 1980). **GA,** also has been shown to affect soluble solids concentration (SSC). Proebsting et al. (1973) reported a delay in SSC accumulation, whereas others have reported that GA, increases SSC (Facteau et al., 1985) or has no effect (Looney and Lidster, 1980).

Firmness, size, and SSC are also important characteristics of brined sweet cherries, but, to our knowledge, no information is available concerning the effects of GA_3 on treated fruit. An important consideration concerns SSC because brined cherries are susceptible to a disorder called solution pockets (SP). SP are transparent areas beneath the skin, most common along the suture, that are filled with ruptured cell contents and brine solution. Affected fruit may tear when pitted, thereby increasing loss of intact fruit (Cameron, 1966). The major factor associated with SP levels is the water : sugar content of fruit. Fruit harvested early in maturation, i.e., at low SSC, usually have low levels of the disorder. Industry practice is to begin harvest when SSC levels are 13% to 14% or to lower fruit moisture content either by harvesting late in the day or delaying brining after harvest (Cain and Smith, 1968; Cameron, 1966).

This paper reports results from 2 years of trials on brined quality of GA_3-treated 'Napoleon' sweet cherry fruit from two orchard districts in Oregon.

We investigated two separate areas in Oregon to gain knowledge over a range of conditions. Experiments were conducted for 2 years on 'Napoleon' sweet cherry fruit harvested over an 8- to 14-day interval. Three and four orchards each in The Dalles (TD) and the Willamette Valley (WV) were used in 1988 and 1989, respectively. GA, (20 $mg \cdot liter^{-1}$) was applied with a handgun (1380 kPa) to runoff on mature trees. There were five single-tree replicates for the GA_3 treatment and five single-tree control trees in each orchard both years. Treatments were applied on 31 May 1988 and 30 May 1989 in TD and 17 June 1988 and 6 June 1989 in WV.

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Table 1. Mean values for brine quality characteristics of GA,-treated 'Napoleon' sweet cherry fruit from two orchard districts in Oregon, 1988 and 1989.

		Willamette Valley (WV)					The Dalles (TD)				
Treatment[z]	Harvest[y]	Drained wt (%)	Fresh wt (g)	Solution pockets (%)	Stemless (%)	Firmness[x] (g)	Drained wt (%)	Fresh wt (g)	Solution pockets (%)	SSC (%)	Firmness[x] (g)
					1988						
GA_3	1	91.1	5.4	2.3	0	707	91.6	5.5	1.6	13.3	779
	2	90.1	6.1	9.2	0	605	90.3	6.6	6.8	13.5	637
	3	91.6	6.6	14.2	0.1	586	91.1	7.6	43.2	16.1	572
	4	92.7	7.2	24.3	0.2	559	90.0	8.4	61.8	16.8	552
Control	1	91.3	6.0	7.4	0.1	646	92.6	5.8	3.0	13.4	731
	2	91.6	6.6	16.1	0	562	92.4	6.7	5.5	14.7	634
	3	93.9	6.9	21.5	0	550	92.4	7.5	40.2	16.6	566
	4	96.3	7.0	30.2	0.1	509	93.9	7.8	56.3	17.9	541
Interaction $LSD_{0.05}$		0.5	0.1	NS	NS	NS	0.7	0.1	NS	0.4	15
					1989						
GA_3	1	85.6	5.9	0.1	1.8	619	82.6	7.5	0.2	15.8	617
	2	92.1	6.1	0.4	2.8	596	85.3	8.1	5.2	17.0	578
	3	91.0	6.9	3.9	2.8	580	84.3	8.6	6.9	18.2	557
Control	1	88.1	6.3	0.2	1	579	85.3	7.2	3.3	15.8	562
	2	94.9	6.4	0.9	4.4	561	89.3	7.5	3.8	16.9	539
	3	95.7	6.9	6.5	9.7	523	93.8	7.3	2.4	17.9	517
Interaction $LSD_{0.05}$		1.0	0.1	1.6	2.1	NS	2.7	0.1	2.5	NS	10

[z]G A_3 applied at 20 mg·liter[-1] to runoff on 31 May 1988 and 30 May 1989 in TD and June 1989 in WV.
[y]Harvest commenced on 22 June 1988 and 20 June 1989 in TD and 29 June 1988 and 19 June 1989 in WV. In both areas, harvests were every 4 to 5 days.
[x]Force required to compress fruit 4.8 mm with a 11.1-mm disk.

Table 2. Mean quality values for GA_3-treated 'Napoleon' sweet cherries from two orchard districts in Oregon, 1988.

Area	Treatment[z]	Drained wt (%)	Fresh wt (%)	Solution pockets (%)	Soluble solids (%)	Stemless (%)	Firmness[y] (g)
			1985				
The Dalles	Area mean	91.8	7.0	27.3	15.3	0.11	627
	GA_3	90.7	7.1	28.4	14.9	0.11	632
	Control	92.8	6.9	26.3	15.7	0.11	621
		**	NS	NS	**	NS	NS
Willamette Valley	Area mean	92.3	6.5	15.6	14.2	0.06	591
	GA_3	91.4	6.3	12.5	13.8	0.07	615
	Control	93.3	6.6	18.8	14.6	0.04	567
		**	**	**	**	NS	***
			1989				
The Dalles	GA_3	84.0	8.0	3.9	16.9	0.53	587
	Control	89.1	7.4	3.3	16.8	0.45	542
		***	***	NS	NS	NS	***
Willamette Valley	GA_3	89.6	6.3	1.5	16.1	2.50	598
	Control	92.9	6.5	2.6	15.9	5.00	558
		***	NS	*	NS	**	***

[z]GA_3 applied at 20 mg·liter[-1] to runoff on 31 May 1988 and 30 May 1989 in TD and 17 June 1988 and 6 June 1989 in WV. Delay refers to time delay after harvest before brining.
[y]Force required to compress fruit 4.8 mm with a 11.1-mm disk.
*,**,***, [NS]Significant at $P < 0.05$, 0.01, or 0.001 or nonsignificant, respectively, according to F test.

In 1988, two, 112-fruit samples were harvested every 4 to 5 days beginning on 22 June in TD and 29 June in WV. Sampling began when fruit SSC was 13% to 14%. Two samples, consisting of 2.5 fruit free from defects and with stems, were picked from each of the four compass quadrants of each tree. The two samples were harvested to determine the effects of brining delays of 6 and 24 h after harvest. There were four sampling dates in each area. In 1989, at least 130 fruit were picked from each tree in a similar manner as in 1988, but only one sample was taken and brined after a 6-h delay. Sampling commenced on 20 June in TD and 19 June in WV, and there were three sample dates in each area.

SSC of juice from a subsample of 10 fruit in 1988 and 2.5 fruit in 1989 was measured with a hand refractometer (Atago model N1, Tokyo). Fresh weight was recorded from the remaining fruit. Fruit from both areas were brined in clear plastic 9.50-ml screw top containers after a 6- or 24-h delay after harvest. The brine volume : cherry weight ratio was 1:1, and brine consisted of 1.5% SO_2 solution adjusted with $Ca(OH)_2$ to an initial pH of 2.7 to 2.9. Drain weight, percentage of fruit with SP or stemless, and firmness were evaluated in December and January the year after treatment. The force (grams) required to compress the fruit 4.8 mm with a 11.1-mm disk was measured on a subsample of 2.5 fruit with a Ametek Hunter Mechanical Force Gauge (Largo, Fla.).

The design was a split plot, with GA, treatment as whole plot and orchards as replicates. Harvest and delay in brining were analyzed as split plots. The two locations (TD and WV) were analyzed separately because of the differences in timing of GA, treatment. Analysis of the data revealed numerous orchard **x** treatment and orchard **x** harvest interactions. In most cases, these were caused by differences in magnitudes rather than different responses. Except for a reduction in incidence of SP in fruit from WV after a 24-h delay, delay in brining did not significantly affect any brine quality characteristic.

Drained weight. Weight loss of cherries associated with brining is the drained weight percentage. For both years and both orchard districts, drained weight of GA,-treated fruit was less than for nontreated fruit (Tables 1, 2, 4, and 5). Both years showed significant treatment × harvest interactions (Tables 1, 4, and 5). GA_3-treated fruit lost more weight than nontreated fruit, and the difference increased as maturity advanced. Normally, drained weight losses decrease as maturity advances so these patterns were consistent with industry observations. Large differences were found between the two years (Tables 1 and 2). The basis of the drained weight changes with maturity and the year-to-year differences are unknown.

Fresh weight. There were significant harvest × treatment interactions for both years

Table 3. Analysis of variance for solution pockets for GA_3/ brine study of sweet cherry fruit from two orchard districts in Oregon, 1988.

	The Dalles				Willamette Valley			
	1988		1989		1988		1989	
Source of variation	Mean square	Significance	Mean square	Significance	Mean square	Significance	Mean square	Significance
Orchard (O)	10,780	****	383	****	2,750	***	103	****
Treatment (T)[z]	263	NS	27	NS	2,375	**	36	**
O × T	181	NS	162	****	247	NS	21	*
Error (a)	280		22		412	NS	76	
Harvest (H)[y]	45,804	****	105	***	5,310	****	308	****
O × H	127	NS	34	*	497	****	90	****
T × H	1,976	****	147	****	15	NS	18	*
O × T × H	150	NS	148	****	165	**	14	*
Error (b)	80		17		65		7	
Delay (D)[x]	103	*			429	****		
O × D	198	***			172	****		
T × D	39	NS			78	**		
O × T × D	13	NS			112	***		
H × D	175	**			78	***		
O × H × D	200	****			60	NS		
T × H × D	3	NS			22	NS		
O × T × H × D	83	NS			21	NS		
Error (c)	33				19			

[z]GA_3 applied at 20 mg·liter^{-1} on 31 May 1988 and 30 May 1989 in TD and 17 June 1988 and 6 June 1989 in WV
[y]Four sampling dates in 1988 and three dates in 1989 in each area. Dates were 4 to 5 days apart.
[x]Brined after delays of 6 or 24 h.
*,**,***,****, [NS]Significant at $P < 0.10$, 0.05, 0.01, or 0.001 or nonsignificant, respectively, according to F test.

Table 4. Analysis of variance table for GA_3/brine study on 'Napoleon' sweet cherry fruit from two orchard districts in Oregon, 1988.

	Drained wt (%)		Fresh wt (g)		Soluble solids (%)		Stemless (%)		Firmness[z] (g)	
Source of variation	Mean square	Significance	Mean square	Significance	Mean square	Significance	Mean square	Significance	Mean square	Significance
					The Dalles					
Orchard (O)	147.1	****	15.0	****	33.1	***	1.90	****	20,613	**
Treatment (T)[y]	264.1	****	0.9	NS	50.9	****	0.00	NS	7,582	NS
O × T	17.4	NS	1.0	NS	2.2	NS	0.08	NS	1,240	NS
Error (a)	7.2		0.7		3.5		0.06		3,991	
Harvest (H)[y]	6.7	**	67.1	****	216.1	****	0.25	***	526,451	****
O × H	0.8	NS	0.1	NS	1.4	NS	0.15	NS	3,686	NS
T × H	26.6	****	2.5	****	3.8	***	0.10	NS	9,777	****
O × T × H	20.4	****	0.4	****	1.0	NS	0.09	NS	895	NS
Error (b)	2.3		0.1		0.7		0.05		1,181	
					Willamette Valley					
Orchard (O)	120.1	****	6.9	***	54.4	***	0.28	**	75,770	****
Treatment (T)[y]	220.2	****	6.2	**	45.4	**	0.07	NS	134,900	****
O × T	21.7	NS	1.6	NS	5.3	NS	0.05		6,928	***
Error (a)	8.6		1.2		7.6	NS	0.06		2,181	
Harvest (H)[x]	166.9	****	22.9	****	1155.1	****	0.25	***	220,934	****
O × H	53.9	****	0.4	****	5.7	****	0.15	**	4,183	***
T × H	32.2	****	1.7	****	1.1	NS	0.10	NS	1,768	NS
O × T × H	2.7	**	1.7	****	1.4	NS	0.09	NS	1,012	NS
Error (b)	1.1		0.1	NS	1.1		0.05		1,262	

[z]Force required to compress fruit 4.8 mm with a 11.1-mm disk.
[y]GA_3 applied at 20 mg·liter^{-1} on 31 May 1988 and 30 May 1989 in TD and 17 June 1988 and 6 June 1989 in WV.
[x]Four sampling dates in 1988 and three dates in 1989 in each area. Dates were 4 to 5 days apart.
*,**,***,****, [NS] Significant at $P < 0.10$, 0.05, 0.01, or 0.001 or nonsignificant, respectively, according to F test.

for both orchard districts (Tables 1, 4, and 5). In all but one instance (TD, 1989), GA_3-treated fruit weighed the least at the first sampling. In all but one instance (WV, 1989), GA_3-treated fruit weighed the most in the last sample. GA, has been shown to increase fruit weight in the Mid-Columbia region in Oregon (Facteau et al., 1985), Canada (Looney and Lidster, 1980), and Washington state (Proebsting et al., 1973) on other cultivars. The lack of a consistent increase in weight in fruit from WV might have been caused by a shorter interval between GA_3 treatment and harvest. There were 22 and 21 days between treatment and first harvest in 1988 and 1989 in TD and 12 and 13 days for the two years, respectively, in WV. Fruit size depends on growth rate and, hence, requires time. We believe that the response to GA, decreases as applications are made closer to harvest (T.J.F., unpublished data). However, GA_3-treated fruit were firmer in both years, indicating that there was a response

Solution pockets. SP levels in 1988 increased as maturity advanced in both orchards districts (Tables 1 and 3). Delay in brining reduced incidence of SP in fruit from WV (6 h, 17.0%; 24 h, 14.3%). The plastic containers may not have allowed sufficient air movement to allow enough moisture loss to show a consistent effect from delay. We did not study delay in brining in 1989. GA, treatment decreased the incidence of SP in fruit from WV in both years (Tables 2 and 3). In 1989, cherries from both districts had statistically significant, but opposite, responses with respect to harvest. At later harvests, GA_3-treated fruit from WV had less

Table 5. Analysis of variance table for GA_3/brine study on 'Napoleon' sweet cherry fruit from two orchard districts in Oregon, 1989.

Source of variation	Drained wt (%)		Fresh wt (g)		Soluble solids (%)		Stemless (%)		Firmness[z] (g)	
	Mean square	Significance	Mean square	Significance	Mean square	Significance	Mean square	Significance	Mean square	Significance
					The Dalles					
Orchard (O)	33.6	NS	1.44	NS	28.77	****	0.77	NS	6,319	***
Treatment (T)[y]	873.2	****	15.45	****	0.74	NS	0.18	NS	59,755	****
O × T	69.4	*	1.04	NS	3.5	*	1.27	NS	884	NS
Error (a)	16.9		0.66		1.47		1.19		1,240	
Harvest (H)*	266.4	****	3.92	****	50.17	****	1.4	*	27,973	****
O × H	19.8	NS	0.53	****	1.95	***	0.61	NS	373	NS
T × H	126.9	***	2.832	****	0.09	NS	0.05	NS	778	*
O × T × H	13.6	NS	0.16	****	1.03	NS	0.29	NS	404	NS
Error (b)	18.9		0.05		0.63		0.48		251	
					Willamette Valley					
Orchard (O)	42.9	****	12.3	****	7.3	*	304.4	****	60,048	****
Treatment (T)[y]	335.0	****	1.2	NS	1.5	NS	192.5	***	49,062	****
O × T	21.8	**	1.7	NS	3.9	NS	38.5	NS	4,804	*
Error (a)	5.1		1.0		2.9		17.6		1,755	
Harvest (H)[x]	578.5	****	6.3	****	143.3	****	236.1	****	18,052	****
O × H	59.5	****	0.3	****	5.6	****	37.7	***	3,003	****
T × H	13.9	***	0.3	***	1.3	*	154.7	****	3,494	NS
O × T × H	6.3	**	0.1	NS	3.7	NS	27.2	**	983	**
Error (b)	2.5		0.1		0.5		11.4		356	

[z]Force required to compress fruit 4.8 mm with a 11.1-mm disk.
[y]GA_3 applied at 20 mg·liter[-1] on 31 May 1988 and 30 May 1989 in TD and 17 June 1988 and 6 June 1989 in WV.
[x]Four sampling dates in 1988 and three dates in 1989 in each area. Dates were 4 to 5 days apart.
*,**,***,****, [NS]Significant at $P < 0.10$, 0.05, 0.01, or 0.001 or nonsignificant, respectively, according to F test.

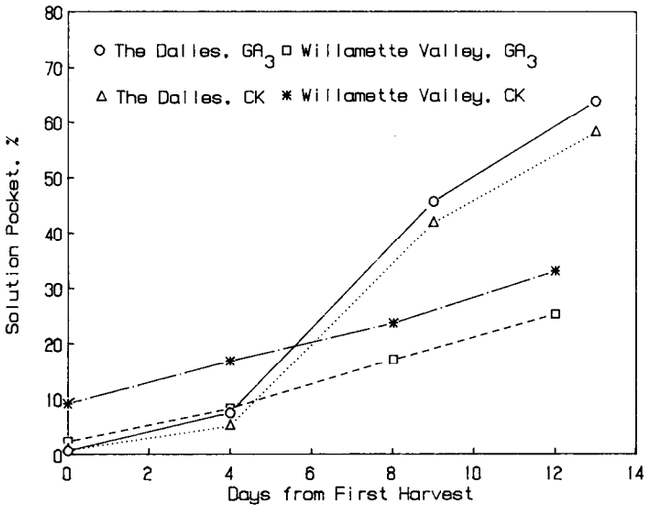

Fig. 1. Relationships between orchard district, days from first sample, and GA_3 treatment for percentage of 'Napoleon' sweet cherry fruit with solution pockets, 1988.

SP than the controls, while similarly treated fruit from TD had more SP than the controls (Table 1). These differences were small, however, as compared to the differences between years (Tables 1 and 2).

In 1988, fruit SSC was highly related to SP levels. Simple correlations were R^2 = 0.64 for TD and R^2 = 0.37 for WV. The slope of the effect of SSC on SP was 4.4 in WV and 11.5 in TD, a significant difference between the two locations. There was a large increase in the incidence of SP as maturity progressed in TD but not in WV fruit (Fig. 1). This response was not evident in 1989 samples, and there was no correlation between SSC and SP; 80% to 90% of the variation in 1989 was due to factors other than SSC (R^2 values for TD and WV were 0.14 and 0.07, respectively). These patterns and the large difference in levels of SP between 1988 and 1989 show that factors other than SSC were involved in SP formation.

Stemless fruit. There were no differences in stem loss during brining in either orchard district in 1988. There was a significant treatment x harvest interaction in fruit from WV in 1989, showing that GA,-treated fruit retained more stems for the second and third harvest dates (Tables 1, 2, 4, and 5). Retention of stems is important for brined fruit destined for some markets. There were large differences in stem retention between the two years and between the orchard districts in 1989 (Table 2), but no obvious explanation is available.

SSC. GA_3 treatment resulted in lower fruit SSC in 1988 at each sample date, but no differences were noted in 1989 for either orchard district (Tables 1, 2, 4, and 5; Fig. 2). This delay in SSC accumulation in GA,-treated fruit has been reported previously (Proebsting et al., 1973), whereas we have reported increased levels (Facteau et al., 1985) and others no effect (Looney and Lidster, 1980). Our 1988 data show that rates of accumulation of fruit SSC were similar for both orchard locations and for treated and nontreated fruit (Fig. 2). This implies that if fruit were delayed in harvest to try and gain size while maintaining acceptable firmness (above 550 g in the system used in this study), fruit SSC could have been similar or higher, depending on the delay.

Firmness. GA, significantly increased the firmness of brined fruit from the first sample date in 1988 in TD (Tables 1 and 4), from all harvest times in TD in 1989 (Tables 1 and 5), and as a main effect in 1988 and 1989 in WV (Tables 2, 4, and 5). In the firmness measuring system used, values < 550 g were considered acceptable. No GA_3-treated fruit were below this value. All nontreated fruit were below this level on the last harvest from both years (Table 1). In effect, GA, treatment allowed harvest delay while maintaining acceptable firmness. That fruit soften as they mature was evident in both years of this study (Table 1). GA_3-treated fruit are known to be firmer (Facteau et al., 1985; Looney and Lidster, 1980; Proebsting et al., 1973), and these data substantiate this response for brined 'Napoleon' fruit.

While no consistent patterns were found

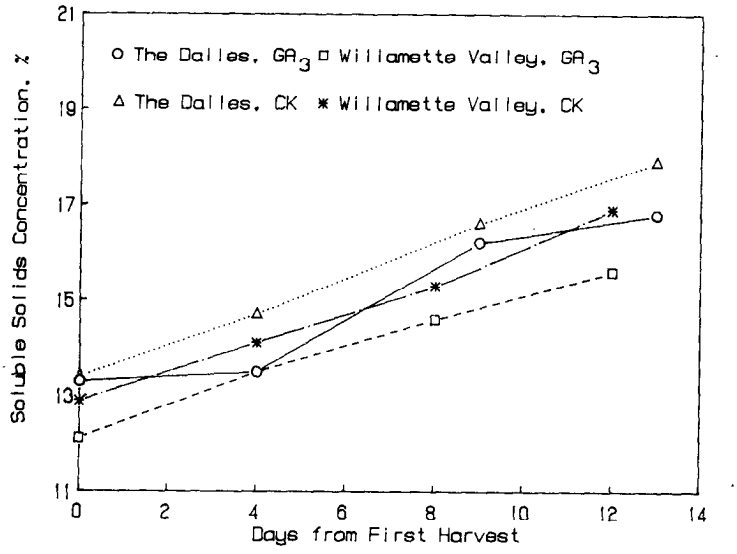

Fig. 2. Relationships between orchard district, days from first sample, and GA, treatment for soluble solids concentration of 'Napoleon' sweet cherry fruit, 1988.

with respect to GA_3 treatments, orchard district and incidence of SP, fruit SSC, and percentage of stemless fruit after brining, drained weight decreased and firmness increased in brined 'Napoleon' sweet cherries treated with preharvest GA_3. Treated fruit weighed less at the first harvest date but more at the last harvest date. We found a relationship between SP and SSC in 1988 but not in 1989. Large differences in SP levels between 1988 and 1989 at similar SSC levels showed that major unknown factors affected SP levels.

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