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CALCIUM-MEDIATED POSTHARVEST CHANGES IN STORAGEABILITY AND FRUIT QUALITY OF PEACHES

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Abstract. **The shelf life and quality attributes of mature-green and mature-ripe peaches [*Prunus persica* cv. 'Surecrop'] were determined following pre- and postharvest applications of CaCl2 (2,000 ppm), Nutrical [8% soluble Ca solution] (2,000 ppm) and an ethylene inhibitor, aminooxyacetate (400 ppm). Periodic samples were taken from fruits stored at 3° C over a period of 7 weeks. Calcium increased fruit firmness and delayed ripening in fruit harvested at two stages of development. TSS, acidity and pH varied at different sampling intervals.**

Harvested fruits undergo a series of processes before reaching the consumer. These processes include precooling, grading, packaging, transportation, and storage. If not performed properly, these processes may exert considerable strain on the texture of the fruit, resulting in cracking, bruising and/or fungal attack. Consequently, the shelf life of fruit is reduced culminating in waste, loss of income to producers, and higher prices to consumers. Pre- and postharvest treatments of fruits to reduce these losses have proven to be effective by delaying fruit ripening and degradation caused by hydrolyzing enzymes, resulting in loss of firmness, increased susceptibility to damage and the weakening of the texture of fruits. (Basiouny and Woods, 1993; Marinos, 1962, Huber, 1983). Calcium has been effective in maintaining texural strength of fruits (Huber, 1983; Dey and Brimson, 1984; Poovaiah 1986). Rossignol et al. (1977) reported that about 60% of calcium is associated with cell wall fractions. The middle lamella-cell wall area is rich in pectinacious materials that interact with Ca^{+2} to form Ca-pectate, thereby enhancing cell to cell cohesiveness (Dey and Brimson, 1984). Conway et al.(1987) reported that Ca reduced ethylene production, polygalacturonase and cellulase activities. These enzymes, among others, are thought to be responsible for cell wall and cutin degradation. The objective of this study was to determine the effects of pre- and post-harvest calcium treatments on quality and shelf life of peach fruits.

Materials and Methods

Twelve peach trees (*Prunus Persica* cv 'Surecrop'), spaced 20 ft by 20 ft and growing on sandy loam soil in Chilton County, Alabama, were used in this study. Trees received a preharvest application of Ca Cl_2 (2,000 ppm), Nutrical (NC) (8% soluble Ca, CSI Chemical Corp.) at a rate of 2,000 ppm, and aminooxyacetate (AOA) at a rate of 400 ppm. A 0.5% Nufilm-17 solution (Miller Chem. and Fertilizer Corporation) was added to enhance penetration.

Two weeks after the initial application, 250 fruit samples were hand picked and placed in field boxes. Immediately after harvest, fruit samples were transported to a forced air refrigerator and precooled at 5° C to remove field heat. After 12 hr., fruit were graded as mature-green (M-G) and mature-ripe (M-R), then vacuum infiltrated using the same chemical formulations at the same concentrations. Samples were washed and dipped in a fungicide solution (Funginex, FMC Corps) before being placed in cold storage (3° C). A total of 30 fruit were sampled weekly from each grade and treatment over a period of 7 weeks for determination of quality attributes.

Firmness was determined using an Effegi penetrometer, Model 327 (Al Fonsine, Italy). Readings were expressed in pounds per square inch (psi). Ca determination was performed using subsamples from each stage of development and treatment. Each fruit was sliced into small portions which were separated into exocarp, mesocarp, and endocarp. Sliced portions were kept in the oven to dry for calcium content determination using a Perkin-Elmer Double Beam Atomic Absorption Spectophotometer, and data were expressed as percentage dry weight. Total soluble solids in each group and treatment were determined with an Atago hand refractometer (Chicago, IL). A total of 24 fruits were sliced and seeds were discarded. Sliced portions were then pulverized, blended, and the pulp was filtered through a double layer of cheese cloth. Total soluble solids (TSS) were in percentages (%). TSS/AC Ratio was determined by dividing the TSS by titratable acidity.

Titratable acidity was determined using 1 ml of juice, 4 ml of deionized water and approximately 200 micro liters of phenolphthaline. Titration was made with 0.1 N NaOH. The results were calculated as percent citric acid. pH of the extracted juice was determined at room temperature with a selective ion analyzer (Fisher Accumet, model 760).

Results and Discussion

Firmness. Ca induced a significant (P>.05) increase in fruit firmness (Tables 1, 3). Data obtained from M-G fruits treated with $CaCl_2$ resulted in 4.7%, 8.8%, 9%, 12.3% and 20% increases in firmness from the 3rd through the 7th week, respectively, over the control. The Nutrical treatment increased firmness from the second week to the seventh week in storage at 0.27%, 4.72% 8.0%, 5.6% and 9.8%, respectively, compared with non-treated fruits. AOA treatments, however, did not increase firmness as much as $CaCl_2$ or Nutrical. AOA is an ethylene inhibitor which reduces ethylene production in a number of fruits and plants (Edward et al., 1982; Faragher et al., 1984). Reduced ethylene production delayed the softening of the cells, which was perhaps due to increased resistance to hydrolyzing enzymes (Faust and Shear, 1972; Poovaiah and Veluthambi, 1986).

Calcium Content. Ca content in fruit that received both preharvest and postharvest calcium application is presented in table 1 and 3 for the two stages of development. Generally, calcium content in the various portions of the fruit was variable depending on the treatment, but was significantly higher than the control. The AOA and control treatments did not show any consistant significant (P>.05) difference in calcium content. Ca content in fruit treated with Nutrical showed progressive decrease from

Table 1. Effect of pre- and post-harvest treatments on quality attributes of peach fruit at mature-green stage[y].

Weeks		Ca content%				Firmness(psi)				TSS%			
		AOA	$CaCl_2$	NC	CON	AOA	$CaCl_2$	NC	CON	AOA	$CaCl_2$	NC	CON
1.						11.0a	11.0a	11.0a	10.9a	9.7d	9.8d	10.8c	11.3a
	EXO.[z]	5.3a	6.7a	6.4b	4.7b								
	MESO.	2.8b	3.8dc	4.2ba	2.8b								
	ENDO.	3.5b	3.4b	4.2a	3.4b								
2.						11.0a	11.0a	1.0a	10.7ba	10.3e	10.2e	11.0b	11.5b
	EXO	4.9a	6.8b	6.5b	4.1a								
	MESO	3.3b	4.3b	3.5b	2.8c								
	ENDO	3.0a	3.8a	4.0bc	2.5c								
3.						11.0a	11.0a	10.7ba	10.4ba	10.0a	10.7ba	11.1b	11.1b
	EXO	4.0a	5.0d	7.3a	4.2a								
	MESO	4.3ba	3.0c	4.5ba	4.3ba								
	ENDO	3.3b	4.1a	4.1a	3.7d								
4.						11.0a	11.0a	10.7b	10.0ba	11.0b	10.8a	11.8ab	11.1b
	XPO	3.9a	5.3b	5.5b	3.7a								
	MESO	3.4b	4.7ba	3.9dc	3.3b								
	ENDO	3.5b	4.3a	3.7d	4.3b								
5.						11.Oa	11.0a	10.7b	10.0ba	10.9b	10.8b	11.8a	11.2c
	EXO	3.3b	4.7c	5.8c	2.6a								
	MESO	3.2b	5.3b	5.5b	3.6a								
	ENDO	3.4b	4.1a	4.1a	2.6c								
6.						10.8a	10.9a	10.3b	9.6bc	11.0b	11.0b	11.8a	12.0a
	EXO	2.7c	6.4a	4.9d	2.3f								
	MESO	3.3c	3.5b	4.1bc	2.6d								
	ENDO	2.6d	5.0a	4.2a	2.4c								
7.						10.8a	10.9a	9.6d	8.6b	12.0a	11.1b	12.0a	11.7b
	EXO	3.8b	4.9d	4.5d	2.8c								
	MESO	3.2b	3.8a	4.0bc	2.5c								
	ENDO	2.6d	4.2b	3.9bc	3.0d								

[y]For each parameter, values within the same week with same superscript are not significantly different at 5% level of probability using Duncan's Multiple Range Test.
[z]Comparison of the three fruit sections of each treatment were made at one time.

Table 2. Effect of pre- and post-harvest treatments on quality attributes of peach fruit at mature-green stage[z].

Weeks	Acidity				TSS/AC Ratio				pH			
	AOA	$CaCl_2$	NC	CON	AOA	$CaCl_2$	NC	CON	AOA	$CaCl_2$	NC	CON
1.	.73a	.70a	.67b	.70a	13.3d	14.0d	16.2c	16.3c	3.6e	3.6e	3.4c	3.6e
2.	.70a	.61b	.59b	.60b	14.7d	17.0c	15.9c	18.9a	3.7a	3.8d	3.8a	3.8a
3.	.63a	.50c	.54b	.56b	15.8d	22.8a	29.4b	20.0a	3.8e	3.9d	3.9d	3.9d
4.	.34e	.52d	.47ba	.38c	32.8cd	23.1c	23.7c	29.0d	3.9d	4.0c	4.0c	3.9d
5.	.55a	.51d	.41bc	.29c	20.0c	27.0cd	28.5b	38.0ba	4.1b	4.2b	4.3b	4.2b
6.	.30d	.32d	.25c	.25c	35.0cd	40.5a	54.6b	46.8c	4.3b	4.3b	4.4b	4.4b
7.	.18d	.23a	.25a	.24a	48.9a	55.0b	47.0a	49.0a	4.4a	4.1a	4.5a	4.5a

[z]For each parameter, values within the same week with same superscript are not significantly different at 5% level of probability using Duncan's Multiple Range Test.

Table 3. Effect of pre- and post-harvest treatments on quality attributes of peach fruit at the mature-ripe stage.[Y]

Weeks		Ca Content%				Firmness (psi)				TSS%			
		AOA	$CaCl_2$	NC	CON	AOA	$CaCl_2$	NC	CON	AOA	$CaCl_2$	NC	CON
1.						10.0b	11.0a	11.0a	10.9a	10.8a	10.8a	11.5ba	11.8ba
	EXO[Z]	5.2b	6.4c	5.3b	4.8a								
	MESO	2.6cd	3.0dc	3.1dc	2.6cd								
	ENDO	3.0d	4.0c	3.4d	3.1d								
2.						10.5b	11.0a	11.0a	10.7b	11.0b	10.5cb	11.0b	11.0b
	EXO	5.8a	5.1bc	5.5a	4.2b								
	MESO	2.8b	4.3b	3.5ba	2.8b								
	ENDO	3.8b	4.8a	4.9a	3.1ba								
3.						10.6b	10.9a	11.0a	0.6b	11.0b	11.0b	12.2ba	11.5ba
	EXO	3.5d	5.7b	5.6b	3.3d								
	MESO	2.2d	4.9a	2.9b	2.2d								
	ENDO	5.0a	4.0cd	5.0a	2.5bc								
4.						10.6a	10.8a	10.9a	10.5b	11.2b	11.0b	11.2b	11.6ba
	EXO	4.4c	5.9ba	5.4b	3.6d								
	MESO	3.6a	4.1b	3.9b	3.6a								
	ENDO	3.9b	3.7b	4.3a	3.8b								
5.						10.8a	10.7a	10.7a	10.4ba	11.1b	11.0b	11.3b	11.8c
	EXO	2.3c	5.8d	4.8c	2.6b								
	MESO	2.6cd	4.7a	3.3bc	2.6cb								
	ENDO	2.9c	4.1a	3.7b	2.0c								
6.						10.7a	10.7a	10.6a	10.0ba	11.2b	11.2b	11.3b	12.0a
	EXO	3.2d	4.9c	6.4a	2.7d								
	MESO	2.4cd	4.1bc	3.5ba	2.4cd								
	ENDO	3.4c	4.2d	5.0a	3.0ba								
7.						10.9a	10.6a	10.3c	9.6b	12.1bc	12.0bc	11.4a	12.1bc
	EXO	2.4a	4.5d	4.9b	2.5a								
	MESO	2.3d	4.0b	3.8b	2.3d								
	ENDO	3.0a	3.9b	4.2c	3.6b								

[y]For each parameter tested, value within the same week with the same superscript are not significantly different at 5% level of probability using Duncan's Multiple Range Test.
[z]Comparison of the three fruit sections of each treatment were made at one time.

the outer tissue (exocarp) to the middle tissue (mesocarp). However, for a reason not presicely understood, the inner portion of the fruit (endocarp) contained more calcium than the middle tissue (mesocarp). The differences in calcium content as expressed as percentage of the control for Ca treatment were 30%, 39%, 32%, 45%, 64.6%, and 42% for the first through the 6th week in storage, respectively. The endocarp portion of the fruit had significantly ($P > .05$) higher Ca compared with the control in weeks 2, 4, 5, 6, and 7 (17%, 25%, 31%, 52% and 29% of the control, respectively). Nutrical treatments for M-G and M-R stages of development showed a similar trend in calcium content compared with control. However,nutrical treated fruit had more Ca recorded in the endocarp portions of the fruit compared with mesocarp. It could be that the proximity of the endocarp to the calyx and epidermal openings, such as the stomata on the exocarp, may be responsible for the differences, as suggested by Lidster et al. (1978).

Total soluble solids. Total soluble solids generally showed increases as the storage period progressed (Table 1, 3). $CaCl_2$-treated fruit showed increases in TSS at M-R stage of development; however, these increases were not statistically significant. On the other hand, Nutrical *treatments* for M-R fruits exhibited significantly ($P > .05$) lower TSS compared with control for weeks 1through4 and 6 at 8.5%, 3.5%, 3.8% and 2%, respectively.

Acidity and pH. Ca-treated fruits were more acidic than the control (Table 2, 4). There was an inverse relationship between acidity and hydrogen ion concentration (pH) in fruits. Generally, increases in pH were recorded for all treatments despite the fact that the differences with control were more apparent for Ca-treatments. Acidity in Ca-treated fruits declined at a slower rate compared with control. Nutrical induced the highest acidity among all treatments. It is evident that Ca application delayed TSS increase and the reduction of acidity in Ca-treated fruits.

Table 4. Effect of pre- and post-harvest treatments on quality attributes of peach fruit at mature-green stage[z].

Weeks	AOA	$CaCl_2$	Acidity NC	CON	AOA	TSS/AC Ratio $CaCl_2$	NC	CON	AOA	pH $CaCl_2$	NC	CON
1.	.63a	.60a	.66b	.63a	17.2c	18.8c	15.6bc	18.3c	3.7c	3.5f	3.6f	3.7c
2.	.66a	.52c	.69b	.66a	16.7c	20.7d	16.2c	15.9c	3.9d	3.8d	3.8d	3.8d
3.	.56a	.53ba	.59a	.57a	19.8c	22.6c	18.8c	20.2c	4.0cd	3.9d	4.0c	3.8d
4.	.38ba	.40ba	.54bc	.34b	29.0b	27.6b	20.6cd	34.0c	4.0b	4.0b	4.0b	3.9b
5.	.28b	.30b	.37ba	.34ba	39.0a	31.8c	30.4c	34.6b	4.4a	4.2b	4.2b	4.3a
6.	.25b	.31c	.30c	.28b	43.0c	41.2c	36.7d	55.2ba	4.3a	4.4a	4.4a	4.5a
7.	.27b	.22e	.19c	.24b	44.5a	56.5ba	58.0ba	47a	4.5b	4.3b	4.4b	4.5b

[z]For each parameter, values within the same week with same superscript are not significantly different at 5% level of probability using Duncan's Multiple Range Test.

Total soluble solids/acid ratio. TSS/Ac ratio gradually increased during the study period. Fruit treated with $CaCl_2$ and picked at M-R stage showed a significantly lower ratio than the control in weeks 4 and 6 at 18.7%, and 25.3%, respectively (Table 2, 4). M-G fruits, on the other hand, were significantly lower in TSS/Acid ratio than the control in weeks 4, 5, and 6. The percent differences from the control were 29.2%, 20.3%, and 21.5%, respectively. M-R fruit of the same treatment differed from the control by 30%, 17.6%, and 16.5% for weeks 4, 5 and 6, respectively. These results agreed with those obtained earlier by Meredith et al. (1989). Changes in TSS did not always correspond to changes in acidity. A higher TSS/Ac ratio does not necessarily mean fruits of superior quality, and a lower TSS/Ac does not signify fruits with inferior quality. Other fruit quality parameters have to be considered.

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