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BLUEBERRY FRUIT QUALITY AND STORABILITY INFLUENCED BY POSTHARVEST APPLICATION OF POLYAMINES AND HEAT TREATMENTS

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Abstract. **Fruits of rabbiteye blueberry (*Vaccinium ashei* Reade cv. 'Tifblue') were hand-picked at horticultural maturity. After pre-cooling at 5°C for 12 hr. to remove field heat, the fruits were divided into six groups and subjected to heat treatment at 37.7°C for 30 min., dipping in 2 polyamines (10.0 mM putresine and 1.0 mM spermine) solutions for 5 min. and a combination of heat and polyamine treatments. Dried fruits after each treatment were transferred to perforated paper pints covered with plastic tops and kept in ventilated cartons at 3 ± 2°C. and 80-90% relative humidity for 4 weeks. Samples taken weekly from each treatment showed that fruits treated with polyamine maintained better qualities than heat treatment. Heat treatment resulted in small, wrinkled fruits with less acceptable characteristics. Combination of polyamine with heat treatments did not improve fruit quality.**

Rabbiteye blueberry (*Vaccinium ashei* Reade) is highly productive in the Southeastern region of the USA. It is tolerant to high summer temperature and has only a moderate chilling requirement making it ideally suitable for many areas throughout the Southeastern States particularly Georgia, Florida and Alabama. Production of many rabbiteye varieties has increased in recent years. Concomitant with the continuing increase in production, is the need for distribution to greater distances from production areas. The problems associated with greater distribution distances is magnified by rapid increase of machine harvesting (Miller and Smittle, 1987; Mainland et al., 1975; Saftner and Baldi, 1990; Sanford et al., 1991). Due to its short shelf-life (Basiouny and Woods, 1992; Basiouny and Chen, 1988), the perishability of the fruit concerns many blueberry producers and processors. Heat treatment have been used to control fungal diseases, insects infestation and to inhibit ripening of various fruits (Couey, 1989; Couey and Follstad, 1966; Lurie and Klein, 1990; Barkai-Golan and Phillips, 1991; Garcia et al., 1996). Polyamines, organic substances of wide spread occurrence in plants, have been reported as modulators of plant growth and development (Dumbroff, 1990; Slocum et al., 1984). They have been implicated in fruit softening, inhibition of ethylene biosynthesis and other plant metabolic processes (Suttle, 1981; Apelbaum et al., 1981; Kramer et al., 1989, 1991; Kushad, 1988). Research on storage of rabbiteye blueberry is limited and attempts to extend fruit market acceptability produced encouraging results (Basiouny, 1994; Basiouny and Chen, 1988; Basiouny and Woods, 1992; Graddick et al., 1986; Miller et al., 1984, 1988). The objectives of this study was to investigate the effects of polyamines and heat treatments on the quality and storability of rabbiteye blueberry fruit.

Materials and Methods

Twelve 19-year-old bushes of rabbiteye blueberry cv. 'Garden blue' (*Vaccinium ashie* Reade) were used for this study. The bushes are planted on a sandy loam soil (pH 4.5 to 5.0) at 1.8 × 3.6 m^2 spacing, and received the cultural practices followed by Tuskegee Agricultural Experiment Station. Shortly after maturity, fruits of each bush were hand-picked in the morning randomly and were transferred to the laboratory. An initial sample was analyzed to assess fruit quality at harvest. After pre-cooling at 5°C for 12 hr. to remove field heat, the fruits were sorted and uniform ones were randomly assigned to six treatments in a completely randomized design with 3 replicates each of 200 fruits as follows: Treatment 1; fruits received heat (H) treatment in which they were heated in an oven at 37.7°C for 30 min., then cooled at room temperature. Treatment 2; fruits received aqueous treatment in which fruits were dipped in a 10.0 mM Putresine (PUT) Solution (Sigma Chemical Company, St. Louis, Mo.). The fruits were held for 2-3 min. in the dipping solution then dried at room temperature using portable fan. Treatment 3; was the same as treatment 2 except for using 1.00 mM Spermine (SPN) solution (Sigma Chemical Company, St. Louis, Mo.). Treatment 4; heated fruits (as in treatment 1) were dipped, after drying, in 10.0 mM Putresine solution Treatment 5; was the same as treatment 4 except 1.0 mM spermine was used as a dipping solution. Treatment 6; fruits were not treated and used as a control. After each treatment, dried fruits were transferred to proferated paper pints covered with plastic tops and kept in ventilated cartons at 3 ± 2°C and 80-90% relative humidity for 4 weeks. Samples were taken weekly for quality attributes determination. Net fruit weight and volume (gain or loss) were calculated on fresh weight bases. Firmness (N), soluble solid contents (% SSC), titrable acidity (% Ac.), SSC/Ac. ratio, pH, total anthocyanin (Ac.), and ethylene measurement were determined as described in previous report.(Basiouny and Woods, 1992).

Results and Discussion

There were obvious differences in blueberry fresh fruit weight and volume among treatments after 1, 2, 3, and 4 weeks in cold storage (Tables 1, 2, 3, and 4). The reduction in weight and volume, which was due to moisture loss from the surface of the fruit, continued throughout the storage period regardless of the treatments. The loss in fresh weight and volume of control fruits was higher after the second week than in treatments. Control fruits lost 7%, 19%, 27% and 28% of their initial weight and 9%, 19%, 26% and 35% of volume after 1, 2, 3, and 4 weeks in cold storage, respectively. While moisture losses from heat-treated fruits were significantly higher after the first week in storage (20% of the initial weight). This was attributed mainly to the effect of heating on the fruit before storage. Dipping the fruits in 10.0 mM putresine solution resulted in the least fruit moisture loss in comparison with moisture losses from fruits heated or dipped in 1.0 mM spermine solution, separately or in combination.

Data on blueberry fruit firmness (Tables 1, 2, 3, and 4) showed a steady decline in firmness as the fruit continued in cold storage. While the treatments resulted in variable firmness values, fruits dipped in putresine solution maintained the highest firmness compared with the control. After 4 weeks

Table 1. Effects of heat and polyamines treatments on blueberry fruit quality after 1 week in cold storage.[z]

	Initial	Cont.	Heat	PUT.	PUT.+H.	SPN.	SPN.+H.
Wt (g/50 f.)	60.31a	55.91b	48.43c	51.38b	46.12c	49.83bc	46.32c
Vol. (cc/50 f.)	57.93a	52.53b	45.12d	49.21c	42.01d	47.12cd	42.13d
Firmness (N)	4.63a	4.17c	4.30b	4.43ab	4.01c	4.00c	3.72cd
SSC (%)	14.82a	15.93a	15.82a	15.44b	15.73a	15.21b	14.77c
Acidity (%)	1.67a	1.27b	1.34b	1.30b	1.35b	1.06c	1.19bc
SSC/Acid (ratio)	8.28d	12.54b	11.81c	11.88c	11.65c	14.35a	12.41b
pH	3.28c	3.51b	3.43b	3.32c	3.41b	3.82a	3.76a
T. Acy	110.06b	118.00a	104.00c	122.00a	110.00b	116.00a	100.00c
Ethylene (ul/kg^{-1}/hr^{-1})	Trace/BD[y]	BD	BD	BD	BD	BD	BD

[z]Average of 3 replicates. Mean separation within rows using Duncan's Multiple Range Test (5% level).
[y]BD = below detection.

Table 2. Effects of heat and polyamines treatments on blueberry fruit quality after 2 weeks in cold storage.[z]

	Initial	Cont.	Heat	PUT.	PUT.+H.	SPN.	SPN.+H.
Wt. (g/50 f.)	60.31a	49.62b	47.00b	50.34b	44.31c	45.22bc	41.71c
Vol. (cc/50 f.)	57.93a	47.01b	44.12bc	48.61b	45.17b	41.73c	41.63c
Firmness (N)	4.63a	3.62b	3.13c	4.32a	3.81b	3.71b	3.42bc
SSC (%)	14.82b	16.21a	15.96a	15.86a	15.82a	15.67a	15.23ab
Acidity (%)	1.67a	1.11bc	1.32bc	1.11bc	1.23b	1.00c	0.97c
SSC/Acid (ratio)	8.28d	14.60b	12.09c	14.29b	12.86c	15.67a	15.54a
pH	3.28b	3.91a	3.88a	3.61ab	3.72a	3.80a	3.96a
T. Acy	110.00bc	117.00b	97.00c	122.00a	118.00b	124.00a	91.00c
Ethylene (ul/kg^{-1}/hr^{-1})	Trace/BD[y]	BD	BD	BD	BD	BD	BD

[z]Average of 3 replications. Mean separation within rows using Duncan Multiple Range Test (5% level).
[y]BD = below direction.

in cold storage, the reduction in blueberry fruit firmness was only 20% of the initial fruits compared with 36.7% and 40% decline in firmness in heat-treated and control fruits, respectively. Firmness of spermine-treated fruits was apparently higher than similar fruits obtained from heat treatment or the control after 2 and 4 weeks yet, this increase was not statistically significant. However, combination of heat and polyamine did not improve fruit firmness.

There was a correlation between the decrease in fruit firmness and the increase in SSC during 4 weeks in cold storage (Tables 1, 2, 3, and 4). As the fruit continued to lose its resistance to puncturing, SSC continued to increase. This increase was expected as a result of natural metabolic processes occur in the fruit during ripening. However, at the termination of the experiment, fruits treated with spermine had the lowest increase in SSC followed by spermine +heat. The highest increase in SSC occurred in putresine-treated followed by control fruits. Despite the fact that these variations were not highly significant the reason for their occurrence was not known at this time. During fruit ripening, there is an inverse relation between SSC and titrable acidity (Ballinger and Kushman, 1970). It was noticed that, despite of treatment, titrable acidity decreased as SSC increased. There was significant reduction in titrable acidity during storage when compared with acidity determined in samples taken after harvest before storage (initial; Tables 1-4). After four weeks in storage, fruits received heat treatment generally had higher acidity than other treatments (Table 4). The lowest acidity value was obtained from fruits treated with spermine solution. In all treatments, the decreases in titrable acidity was parallel to increases in pH values of fruit juice. Juice from fruits treated with spermine solution had the lower pH values than juice from other treatment. This indicated the superiority of spermine treatment over other treatments in terms of maintaining low SSC and low juice pH. Figures on SSC/T.ac. ratios obtained during storage were variable and not consistent. This was mainly due to the differences in SSC and T. ac. of the fruits during storage. This, however, should not imply that

Table 3. Effects of heat and polyamines treatments on blueberry fruit quality after 3 weeks in cold storage.[z]

	Initial	Cont.	Heat	PUT.	PUT.+H.	SPN.	SPN.+H.
Wt. (g/50 f.)	60.31a	44.90b	44.61b	49.34b	44.00b	40.03b	42.31bc
Vol. (cc/50 f.)	57.93a	43.13bc	43.23bc	48.12b	45.23b	37.19c	40.13c
Firmness (N)	4.63a	3.41b	2.81c	3.89b	3.42b	3.00c	2.64c
SSC (%)	14.82c	16.71a	15.12b	15.72b	16.01ab	16.14a	16.36a
Acidity (%)	1.67a	0.86c	1.23b	1.22b	1.00bc	0.88c	0.73c
SSC/Acid (ratio)	8.28d	19.43a	12.29c	12.89c	16.01b	18.34a	22.41a
pH	3.28c	4.23a	4.02b	3.91b	4.01b	4.33a	4.14a
T. Acy	110.00b	108.00b	100.00bc	108.00b	115.00a	104.00b	82.00c
Ethylene (ul/kg^{-1}/hr^{-1})	Trace/BD[y]	BD	BD	BD	BD	BD	BD

[z]Average of 3 replications. Mean separation within rows using Duncan Multiple Range Test (5% level).
[y]BD = below detection.

Table 4. Effects of heat and polyamines treatments on blueberry fruit quality after 4 weeks in cold storage.[z]

	Initial	Cont.	Heat	PUT.	PUT.+H.	SPN.	SPN.+H.
Wt. (g/50 f.)	60.31a	37.31d	40.11c	48.74b	40.13c	43.41c	38.49d
Vol. (cc/50 f.)	57.93a	37.83c	37.36c	48.32b	38.24c	40.32c	39.10c
Firmness (N)	4.63a	2.77c	2.94bc	3.71b	3.10bc	3.10bc	2.00d
SSC (%)	14.82c	15.62b	15.31b	15.43b	16.23a	13.92d	14.65c
Acidity (%)	1.67a	0.80c	1.30b	1.01b	0.87c	0.34d	0.79c
SSC/Acid (ratio)	8.28c	19.53b	11.78b	15.28b	18.66b	40.94a	18.54b
pH	3.28b	4.44a	4.91a	4.27a	4.70a	3.82b	4.81a
T. Acy	110.00a	86.00c	90.00c	101.00b	82.00d	81.00d	74.00c
Ethylene	Trace/BD[y]	BD	BD	BD	BD	BD	BD

[z]Average of 3 replications. Mean separation within rows using Duncan Multiple Range Test (5% level).
[y]BD = below detection.

high SSC/Ac, ratio necessarily means superior quality, and that a low ratio always indicates inferior quality. In fact, fruits with low ratio may sometimes be far better in quality compared to these with unusually high ones (Basiouny, 1994).

Ripe blueberry fruits are normally blue due to the presence of anthocyanins (Acy) in the epidermal and hypodermal cells (Ballinger et al., 1972). Total anthocyanin was reported to increase in 'Wolcott' highbush blueberry (Ballinger and Kushman, 1970). However, T. Acy did not follow a certain pattern during storage and with different treatments (Tables 1, 2, 3, and 4). In fact, T. Acy continued to decrease as cold storage period increased. Further more, no correlation was found between T. Acy and SSC/Ac. ratios. This was contrary to the findings reported by Ballinger et al., 1970, 1972) which could be attributed to cultivars differences. At the end of four weeks, fruits treated with putresine solution were significantly higher ($P>0.05\%$) than fruits from other treatments (Table 4).

The amount of ethylene in fruits analyzed immediately after harvest was below 1 ppm of detection (Tables 1, 2, 3, and 4). Ethylene was not produced from blueberry fruits soon after detachment or in storage. These confirmed previous finding by Basiouny and Woods (1992). Despite the fact that rabbiteye blueberry has a definite climacteric rise in respiration and should be considered a climacteric-type fruit (Lip, 1978), it is not a high ethylene produce. A previous report (El-Agamy et al., 1982) indicated that significant reduction in ethylene evolution occurred as the fruit started turning blue.

In this study, the use of heat and polyamines as methods of extending rabbiteye blueberry storability and shelf-life benefited the fruits by maintaining better fruit quality than the control after four weeks in storage. Heat treatment, however, resulted in fruits with no signs of decay and looked compatible with other treatments, although some of these fruits were not marketable and unacceptable. Many of the fruits were small and some were wrinkled with less attractive color due to heat and moisture loss. Although prestorage heat treatments of many large fruits are a promising alternative to chemical treatments (Klein and Lurie, 1992), several aspects of using this method for small fruits require continued research to determine the heating regime for a specific commodity. The use of polyamines as a prestorage aqueous treatment for small fruits is quite encouraging. However, future research aimed toward determining the proper polyamines concentrations vs. stage of maturity and/or ripening for each commodity is needed at this time.

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LYCHEE COLOR CAN BE BETTER MAINTAINED IN STORAGE THROUGH APPLICATION OF LOW-PH CELLULOSE COATINGS

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Abstract. **Lychees, harvested in May and June, 1996, were coated with Nature Seal™ formulations designed to lower surface pH toward 4.0 and thereby prolong the red color of fruits throughout cold and ambient temperature storage. Coating formulations applied to 'Mauritius' fruit contained 2% low viscosity hydroxypropyl cellulose with a 0.075 M citrate buffer that maintained pH at either 3.31, 3.9, or 4.84. These treatments had little effect on fruit surface pH, which ranged from 6.0 early in the season to 5.7 at the end. However, a formulation of 3% medium viscosity hydroxypropyl cellulose with 0.1 M citric acid and a pH of 2.3 applied to 'Brewster' fruit significantly reduced surface pH as low as 4.85. Treated fruit in vented plastic bags maintained their color throughout 10 days of storage at 5°C (41°F). Fruit covered with this low-pH film also retained their red hue longer than uncoated fruit or those coated with the film of pH 4.84 during an additional 3 days at 24°C (76°F).**

Led by expanding markets near centers of Asian immigration, demand for lychee (*Litchi chinensis* Sonn.) fruit within the U.S. has doubled since 1990. Land under production in South Florida has risen from 160 acres in 1987 to 511 acres in 1995, from which 2,141 tons of fruit were harvested with a value of $8.57 million (Anonymous, 1996).

The appearance of lychees at the market catches the eye of the casual shopper, who often finds the bright red color appealing. Conversely, a display of lychees that appear dry and brown may be passed over by those unfamiliar with this fruit. Preserving the color of lychees is a prime consideration for successful marketing, and more postharvest research is focused on this quality aspect than on any other.

We would like to thank Everton Bather and Holly Sisson for their technical assistance and Mr. & Mrs. Noble Hendrix, Mr. & Mrs. Jack Gordon, Mr. & Mrs. Paul Ross, and Mr. & Mrs. Mike McCann who provided the fruit used in these experiments. Mention of a trade name does not constitute a recommendation by the U.S.D.A.

The red anthocyanin pigment in the pericarp of lychees is degraded enzymatically when this exterior covering is injured or becomes desiccated (Fourie, 1990; Underhill and Simons, 1993). Injury may result from bruising, attack by postharvest pathogens, or excessive chilling during storage. Besides improving handling and storage procedures, color can be maintained through chemical means postharvest. Exposing fruit to sulfur dioxide gas inhibits enzymatic and nonenzymatic browning and controls decay microbes (Fourie, 1990; Schutte et al, 1991; Tongdee, 1994). Various methods have been examined, often in combination with hydrochloric acid (Fourie, 1990; Underhill et al, 1992; Jiang et al, 1997). The gas bleaches the fruit and inhibits polyphenol oxidase, then an immersion in acid of pH 0.3 to 1.0 permanently restores the red color (Zauberman et al, 1991). The surface pH after such treatment is 4.1 to 4.4.

Fruit coatings based upon sucrose esters or cellulose have not been found to affect the color of lychee pericarp in storage to any commercial advantage (Kremer-Kohne and Lonsdale, 1991; York, 1994). These materials, however, provide a convenient substrate for delivering and maintaining surface-active agents, such as fungicides, acidulants, or antioxidants, at the coated surface (Baldwin et al, 1995). Reducing the pH of these coatings from the range of 6.0 to 7.0 by incorporating an organic acid may improve color retention by lychees in storage.

The objective of this work was to develop low-pH coatings for lychees based upon Nature Seal™ formulations (Nisperos-Carriedo and Baldwin, 1994) incorporating hydroxypropyl cellulose and citric acid. The effect of these coatings on color retention by the pericarp, decay, and chilling injury was evaluated over prolonged storage periods using the two cultivars most widely grown in South Florida, 'Mauritius' and 'Brewster' (Knight, 1994).

Materials and Methods

In an initial trial, ripe 'Mauritius' fruit were harvested at three dates during May and June, 1996, from each of three farms in Dade County, Florida. The farms represented three experimental replications. At each harvest date 60 fruit were cut from the panicles and randomized. Surface color was re-