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Storage Quality Evaluation of Southern Highbush Blueberry Cultivars Jubilee, Magnolia and Pearl River

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Abstract

Fruit of recently released southern highbush blueberry cultivars Jubilee, Magnolia and Pearl River (*Vaccinium spp,* mostly *corymbosum*) and rabbiteye cultivars Climax and Premier (*Vaccinium ashei*) were compared for storage quality. Physical characteristics and chemical composition before and after 28 days storage at 1-3° C were the bases of comparison. Poststorage values of most quality parameters varied with cultivar, and there were changes during storage. 'Climax' and 'Jubilee' had the highest concentrations of glucose and fructose and were the most firm and least decayed after storage. Overall, fruit from the southern highbush cultivars were smaller, had higher weight loss, more shrivel and were less firm than the rabbiteye cultivars. Rabbiteye fruit were much higher in anthocyanins than southern highbush fruit; anthocyanin content of all cultivars increased during storage. The organic acid profile of southern highbush cultivars was similar to those reported for highbush berries. Using a rating system based on means separations of quality factors within cultivars, the estimated overall storage quality of the cultivars in decreasing order was 'Climax,' 'Jubilee,' 'Premier,' 'Magnolia' and 'Pearl River.'

Introduction

Blueberry growers in the coastal plain region of the southeastern United States would like to have commercial cultivars which ripen before 'Climax' and 'Premier,' two widely-grown early-ripening rabbiteye cultivars, so they can take advantage of traditionally higher prices paid for early fresh-market fruit. Southern highbush blueberries require low chilling and typically ripen before most rabbiteyes; Ehlenfeldt *et al.* (2) and Lyrene (9) described their development and some earlier released cultivars.

Southern highbush cultivars Jubilee, Magnolia and Pearl River were released December, 1994, by the United States Department of Agriculture, Agricultural Research Service, from the breeding program at the Small Fruit Research Station, Poplarville, Mississippi, and are recommended for trial on the southeastern coastal plain (15). They bloom 5 to 12 days later than 'Climax' and 'Premier' but have ripe berries 5 to 7 days sooner. Periods of warm weather in late winter or early spring in this region can result in early blooming of 'Climax' and 'Premier.' The later blooming of these new releases may avoid frosts or freezes that often follow the warm weather. Indeed, in 1996, 60-75% of 'Climax' and 'Premier' blooms were killed when a late freeze followed advanced flowering. 'Jubilee,' 'Pearl River' and 'Magnolia' had less than 10% bloom loss.

The postharvest quality of southern highbush cultivars is widely variable. Some early releases had postharvest quality problems which limited their commercial use. For example, 'Sharpblue' fruit was found to soften quicker during storage than that of rabbiteye cultivar Climax (13). Lang and Tao (8) compared two southern highbush cultivars and reported 'Gulfcoast' fruit performed better under extended storage than did 'Sharpblue' fruit. The undesirable tendency of the pedicel to remain attached to 'Gulfcoast' berries (stemming) has been reported (2, 8, 14). More recernt southern highbush releases show improved postharvest quality.

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Perkins-Veazie and coworkers (14) evaluated shelf life quality of seven southern highbush cultivars and selections and compared them with storage quality of highbush cultivars Sierra and Bluecrop and with rabbiteye cultivar Climax. They ranked fruit of two southern highbush clones similar to 'Climax' as having excellent postharvest quality.

This study was part of a research program to provide a wide base of cultural, processing and quality information for the new southern highbush releases. Many area growers lost most of their early-season berries to the 1996 freeze and are very interested in these cultivars which may offer a week's protection from low temperature damage plus provide ripe berries a week earlier than 'Climax' and 'Premier.' Grower demand for plants for 1997 exceeded supply. The objective of this study was to provide storage quality information to help evaluate the commercial potential of the new releases by comparing their storage quality to that of the widely planted early-ripening rabbiteye cultivars Climax and Premier. Physical characteristics and chemical composition measured before and after refrigerated storage were used to evaluate and compare storage life quality.

Materials and Methods

Four plants each of 'Jublilee,' 'Magnolia,' 'Pearl River,' 'Climax' and 'Premier' were chosen in early 1996 from the Small Fruit Research Station experimental plantings in Stone County, Mississippi. 'Jubilee,' 'Magnolia' and 'Pearl River' were hand-harvested May 29, June 3 and June 4, respectively. 'Climax' and 'Premier' were harvested June 12. Fruit harvested from each of the four plants of each cultivar was considered a replicate.

Berries were harvested as soon as the dew had dried and while still cool in the early morning; they were in the laboratory within an hour of harvest. After sorting to remove immature, overripe or damaged fruit, berry weights were determined as the mean weight of 30 berries of each replicate. Samples from each replicate were put into pint freezer bags and frozen at –20° C for later analysis to establish prestorage composition. For refrigerated storage, approximately 150 g of berries of each replicate were weighed into each of four half-pint (250 ml) vented clear plastic "clamshell" retail containers (BT-8 PETE , Fabri-Kal Corp., Kalamazoo, MI). Containers were randomly placed (single layer) into corrugated commercial flats. The flats were double-stacked on the middle two shelves of a 50 cu. ft. laboratory refrigerator and held at 1-3° C and 88-92% RH for 28 days. When removed from storage, retail containers of berries were held at room temperature (24° C) for two hours to permit condensate to evaporate before weighing to calculate storage weight loss. Berries from two randomly selected clamshells of each replicate were sampled for berry weight measurements and for subjective estimations of decay, shrivel and firmness. Samples were frozen for poststorage compositional analyses.

Initial values of the subjective parameters decay, shrivel and firmness for the freshly-harvested and sorted fruit were assumed to be "1." Poststorage decay was estimated by examining stem scars of 10 randomly selected berries from each replicate for leakage or fungal growth under a dissecting microscope. On a 1-4 scale, 1 = no visible growth, 2 = slight (strands of mycelium visible), 3 = moderate (mycelial strands or tufts of mycelium visible without using the microscope) and 4 = heavy (growth not contained within the stem scar). Any evidence of leakage was assigned a rating of 3. Shrivel also was estimated on a 1-4 scale where 1 = skin surface smooth, no wrinkles, 2 = slight wrinkling of skin around the stem scar, 3 = wrinkling of stem scar shoulder and equatorially, some pitting, and 4 = extensive wrinkling and pitting. Subjective firmness was estimated by rolling berries between the thumb and index finger while applying moderate pressure. Berries not yielding to moderate pressure were rated 1 = firm, 2 = slight yielding, 3 = yielding easily, and 4 = very soft or mushy.

Frozen berries from all treatment units were analyzed for total solids (TS), soluble solids concentration (SSC), titratable acidity (TA), pH, anthocyanin content (ACY), sugars and organic acids. Chemical and related physical measurements were taken on subsamples of a puree made by blending 40 g of partially thawed blueberries with a Waring Commercial Blender. Fruit pH and TS were measured on puree. TA was determined by adding 10 g of puree to 100 ml deionized water and titrating to pH 8.2 with 0.1 N NaOH, and was expressed as % citric acid on a fresh weight basis. SSC was measured with a hand-held refractometer using liquid from puree filtered through four layers of grade 50 cheesecloth. To estimate ACY content, 1 g of puree was extracted twice (Brinkman PT10/35) with 20 ml of 95% reagent ethanol:0.1 N HCl (85:15) and centrifuged at 2580 X g for 10 minutes. Supernates were combined and made to 50 ml with extraction solution; absorbance at 535 nm of a 1:10 dilution of this solution was measured. ACY content was expressed as absorbance units per g of fresh weight (14).

Sugars and organic acids were determined by high-performance liquid chromatography. The extraction procedure used was a modification of that reported by Kalt and McDonald (6). One g of puree was homogenized with 10 ml of deionized water and centrifuged 10 minutes at 1000 g. Five ml of supernatant were put through a Waters C_{18} Sep-Pak which had been rinsed with 5 ml methanol followed by 5 ml deionized water. The last 2 ml of effluent from the Sep-Pak were collected and filtered through a 0.45 µm nylon membrane filter; sugars and acids were determined from this filtrate. Sugars in a 20 µl sample were separated on a Supelcosil LC-NH_2 , 5 µm, 250 x 4.6 mm column by elution with 3:1 acetonitrile:water, flow 1.0 ml/min; peaks were detected with a Waters 401 refractive index detector. Organic acids in a 20 µl sample were separated on a BioRad HPX-87H organic acid column by elution with 0.005 M H_2SO_4, flow 0.6 ml/min; peaks were detected by ultraviolet absorption at 210 nm with a Waters 486 tunable absorbance detector. Peaks were identified and quantified by comparison with internal and external standards. A Waters 510 pump was used for both analyses.

The study was conducted as a split-plot design with cultivar (four replications) as the main plot and storage as subplots. Statistical differences were determined by analysis of variance using the general linear models procedure of the Statistical Analysis System (SAS Institute, Carry, NC). Within the main effect of cultivar, means were separated by LSD, ❣ P 0.05 and between storage days by t-test, P ❣ 0.05.

Results and Discussion

Changes in retail-important quality factors (retail unit weight loss, berry weight, firmness, shrivel and decay) after storage varied with the cultivar (Table 1). 'Pearl River' lost significantly more weight (moisture) per retail unit than did the other cultivars, while changes in average berry weight within cultivars were not significant. Berries of all cultivars became more shriveled and less firm. 'Climax' and 'Premier' were less affected by shrivel; 'Pearl River' was considered unsalable after storage because of shrivel. 'Pearl River' has less surface wax than the other cultivars (10) which may have contributed to its higher retail-unit weight loss and poststorage shrivel. Surface wax is partially responsible for the familiar "bloom" of blueberries and may help retard moisture loss during storage. 'Climax' and 'Jubilee' remained firmer than the other three cultivars. Low incidence of fungal growth and leakage after storage (none was noted in 'Climax' and 'Jubilee') was attributed to small, dry stem scars, low storage temperature, and to harvesting and handling procedures; fruit was hand-picked early in the day and processed for storage within three hours of harvest.

Poststorage values for TS, TA, SSC and sugar/acid ratio (SSC/TA) varied among cultivars, while within each cultivar there were no significant changes in these values during storage (Table 1). SSC/TA val-

Table 1. Quality attributes of southern highbush blueberry cultivars Jubilee, Magnolia, and Pearl River and rabbiteye cultivars Climax and Premier after 28 days at 1-3° C and 88-90% RH.

Cultivar	Berry wt[z] g	Wt loss[y] %	Shrivel[y]	Decay[y]	Firmness[y]	TS[z] %	SSC[z] %	TA[z] %	SSC/TA[z]
Jubilee	1.59 c	5.94 b	2.26 bc	1.00	1.69 b	15.25 b	14.28 b	0.90 a	15.86 d
Magnolia	1.49 c	6.42 b	2.47 b	1.20	2.46 a	12.75 b	11.27 d	0.85 a	13.76 d
Pearl River	1.89 b	8.51 a	3.29 a	1.15	2.68 a	14.75 b	12.75 c	0.58 b	21.98 c
Climax	1.86 b	6.81 b	1.70 c	1.00	1.39 b	20.38 a	15.47 a	0.51 b	30.83 b
Premier	2.14 a	5.74 b	1.95 c	1.20	2.24 a	18.00 a	15.18 a	0.35 b	43.37 a

[z]Storage changes not significant, p ≤ 0.05. Cultivar means shown.
[y]Initial values assumed to be 0.
[x]Means not followed by the same letter are different, P ≤ 0.05, LSD

ues for 'Jubilee' and 'Magnolia' were less than the 18 or lower which has been associated with improved keeping quality in highbush fruit (4). The value for 'Pearl River' was slightly higher, and values for 'Climax' and 'Premier' were much higher. A similar high value for 'Premier' was found in 1995 (10). SSC/TA values higher than 18 for 'Climax,' noted for its good keeping quality, have been reported (11,14). Makus and Morris (11) reported a mean of 32.5 for three rabbiteye cultivars with a high value of 48.2; they suggested the relationship between keeping quality and sugar/acid ratio may not hold true for rabbiteye blueberries. Poststorage pH values differed among cultivars (Table 2), but all were less than the 3.5 usually related to good storage quality (1). Initial pH of 'Jubilee' and 'Climax' were less than 3.0, and both increased after storage. The pH values for 'Pearl River' decreased while those of 'Magnolia' and 'Premier' did not differ after storage.

Interaction of organic acids and sugars play important parts in flavor and consumer acceptance of fruit (12). Kalt and McDonald (6) reported fruit acids composition of lowbush blueberries and suggested sensory properties of blueberry species may differ because of different taste characteristics contributed by the fruit acids. Organic acid compositions of highbush, rabbiteye and albino-fruited highbush blueberries were reported by Ehlenfeldt *et al.* (3). The concentration of each acid in each cultivar was higher after storage (Table 2), and the higher concentrations were significant in 'Jubilee' (citric, malic), 'Pearl River' (citric, succinic) and

Table 2. pH values and concentrations (fresh weight basis) of sugars, organic acids and anthocyanins in southern highbush blueberry cultivars Jubilee, Magnolia, and Pearl River and rabbiteye cultivars Climax and Premier before and after 28 days at 1-3° C and 88-90% RH.

Cultivar	Day	Fructose mg/g	Glucose mg/g	Total sugars mg/g	Citric mg/g	Malic mg/g	Quinic mg/g	Succinic mg/g	Total acids mg/g	pH	ACY AU/g[z]
Jubilee	0	47.61	46.58	94.17	5.47	1.84	0.57	2.71	10.57	2.96	84
	28	63.75*	61.14*	124.89*	9.23*	3.33*	0.77	3.38	16.71*	3.37*	100*
Magnolia	0	33.23	36.52	69.75	6.56	1.61	0.4	1.65	10.21	3.11	101
	28	33.88	37.91	71.78	6.62	1.89	0.4	1.88	10.74	3.00	133*
Pearl River	0	39.21	37.24	76.45	2.38	1.51	0.96	3.63	8.48	3.47	81
	28	55.41*	54.21*	109.61*	4.29*	3.09*	1.99	6.57*	15.95*	3.22*	97*
Climax	0	59.39	61.91	121.30	0.66	1.89	1.34	10.09	13.98	2.91	123
	28	69.16	65.24	134.40	0.77	2.89	1.54	13.26	18.46	3.17*	224*
Premier	0	63.53	63.44	126.97	1.42	2.17	1.24	5.68	10.51	3.12	171
	28	53.71	48.03*	101.74	1.69	3.42*	1.68*	5.82	12.61	2.99	227*

[z]Absorbance units/g.
*Significantly different, P ≤ 0.05, t-test.

Table 3. Summary of blueberry quality after 28 days at 1-3° C and 88-90% RH[z]

Cultivar	Berry weight	Weight loss	Shrivel	Decay	Firm	Total sugars	Total acids	Total score
Jubilee	3	1	1.5	1	1	1	2	10.5
Magnolia	3	1	2.5	2	2	3	4	17.5
Pearl River	2	2	3.0	2	2	2	2	15.0
Climax	2	1	1.0	1	1	1	1	8.0
Premier	1	1	1.0	2	2	2	3	12.0

[z]Total score determined by summing scores across columns. Scores within columns derived from mean value rankings in tables 1-2. Lower scores indicate better fruit quality.

'Premier' (malic, quinic). Poststorage concentrations of total acids also were higher for each cultivar, but the changes were significant only for the southern highbush cultivars Jubilee and Pearl River. Increased acid concentrations were not reflected by changes in TA and pH values. Kalt and McDonald (6) reported a poststorage decline in TA of lowbush blueberries although there were increases in five of the nine acids they measured. Expressed as mean percentages of total acids, the contributions of citric, malic, quinic and succinic acids in the southern highbush cultivars were 45%, 19%, 7% and 29%, respectively, which formed an organic acid profile similar to that reported by Ehlenfeldt *et al.* (3) for highbush blueberries. Ehlenfeldt and coworkers feel that blueberry species may be distinguished by their organic acid profiles, and this profile may be indicative of the *V. corymbosum* heritage of southern highbush. In the rabbiteye cultivars, the mean contributions of succinic, malic, quinic and citric acids were 63%, 19%, 10% and 8%, respectively, and their organic acid profile was similar to the rabbiteye profile reported by Ehlenfeldt *et al.* (3).

There were significant increases in fructose and glucose concentrations in 'Jubilee' and 'Pearl River' during storage, while both decreased in 'Premier.' These changes were not paralleled by changes in SSC. Average difference in sugar content estimated by refractometer (SSC) and the lower total fructose + glucose measured by HPLC was 22%. Part of this difference was the contribution of dissolved acids to SSC values. Sucrose was not detected.

Anthocyanins, interacting with other chemical components, are the pigments responsible for colors of blueberries. Compared to other fruit, blueberries have high levels of anthocyanins. In addition to their role as pigments, blueberry anthocyanins may prove beneficial in human health as dietary antioxidants (5). 'Climax' and 'Premier' had significantly higher ACY values, and the ACY values of all cultivars were higher after storage. Other workers have reported ACY increases after storage (6, 7, 14).

A ranking system developed by Perkins-Veazie *et al.* (14) was used to compare overall storage quality among cultivars (Table 3). Based on mean value separations within each retail-important quality parameter from Tables 1 and 2, a numerical value was assigned for each cultivar. The cultivar with the "best" value was assigned a value of "1," the next best cultivar received a "2," etc. Values not statistically different received the same number. Numbers were summed across columns to get a total score for each cultivar. With this system, 'Climax' ranked highest in overall storage quality followed by 'Jubilee' and 'Premier.' 'Pearl River' was ranked lowest in overall storage quality.

In summary, results of this study indicate the storage qualities of 'Jubilee' 'Climax' and 'Premier' essentially are equivalent and affirm that 'Jubilee' merits the interest shown by growers in the region, especially when considered with its late blooming and early ripening characteristics. 'Magnolia' did not score as highly as 'Climax,' 'Jubilee' and 'Premier,' but has

good storage quality and also should be considered by area growers.

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Significant contributions to the science and practice of pomology other than through fruit breeding will also be considered. Such contributions may relate to any important area of fruit production such as rootstock development and evaluation, anatomical and morphological studies, or noteworthy publications in any of the above subjects.

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