McGuire, R. G. 1992. Reporting of objective color measurements. HortScience 27:1254-1255.
Mitchell, F. G. 1992a. Cooling horticultural commodities. I. The need for cooling, p. 53-56. In: A. A. Kader (ed.). Postharvest technology of horticultural crops. Publ. 3311. University of California.
Mitchell, F. G. 1992b. Cooling horticultural commodities. II. Cooling methods, p. 56-63. In: A. A. Kader (ed.). Postharvest technology of horticultural crops. Publ. 3311. University of California.
Mitchell, F. G. 1992c. Postharvest handling systems: small fruits (table grapes, strawberries, kiwifruit), p. 223-231. In: A. A. Kader (ed.). Postharvest technology of horticultural crops. Publ. 3311. University of California.
Mitchell, F. G., E. C. Maxie and A. S. Greathead. 1964. Handling strawberries for fresh market. Calif. Agric. Exp. Station Ext. Serv. Circular 527.
Nunes, M. C. N., J. K. Brecht, A. M. M. B. Morais and S. A. Sargent. 1995. Physical and chemical quality characteristics of strawberries after storage are reduced by a short delay to cooling. Postharv. Biol. Technol. (in press).
Roa, R. D., J. H. di Pendima and D. R. Guemes. 1977. The technical feasibility of export of fresh strawberries to Germany by air. Revista del Instituto de Technologia de Alimentos 2:79-88.
Rose, D. H. and E. A. Gorman. 1936. Handling, precooling, and transportation of Florida strawberries. Florida Agric. Exp. Station Technical Bulletin 525.
Ryall, A. L. and W. J. Lipton. 1979. Handling, transportation and storage of fruits and vegetables. 1. Vegetables and melons. AVI, Westport, Conn.
Ryall, A. L. and W. T. Pentzer. 1982. Handling, transportation and storage of fruits and vegetables. 2. Fruits and tree nuts. AVI, Westport, Conn.
Talbot, M. T. and K. V. Chau. 1991. Precooling strawberries. Florida Coop. Ext. Serv. Circular 942.
Terada, M., Y. Watanabe, M. Kunitoma and E. Hayashi. 1978. Differential rapid analysis of ascorbic acid and ascorbic acid-2-sulfate by dinitrophenylhydrazine method. Anal. Biochem. 84:604-608.

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POSTHARVEST QUALITY OF SOUTHERN HIGHBUSH BLUEBERRIES

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Abstract. **The early ripening southern highbush blueberry is a valuable commodity, but little is known about fruit quality or shelflife of the new cultivars and breeding selections. 'Cape Fear', 'Cooper', 'Gulfcoast', 'O'Neal' and the breeding selection MS108, were harvested in Arkansas in 1993 and 1994. 'Sierra', which has some southern highbush parentage, and the rabbiteye cultivars 'Climax' and 'Tifblue' were also included. Fruit were held at 5C, 90% RH for 21 days then one day at 20C, 80% RH. Southern highbush fruit weights ranged from 1.5 g for 'Cooper' to 2.1 g for 'O'Neal'. 'Climax', 'Tifblue', 'O'Neal', and 'Sierra' fruit had the smallest stem scar diameters (1.3 to 1.5 mm). Following storage, soluble solids concentration changed little. 'Sierra' fruit had very little (<10%) decay. 'Gulfcoast' and 'Cooper' fruit were considered the least acceptable of the clones studies due to high percentages (20 to 30%) of pedicel adherence, decay and soft fruit, and large stem scar tears. 'Sierra' and 'O'Neal' fruit were judged to be as good as or better in postharvest quality than the commercially important 'Climax' and 'Tifblue' cultivars.**

The storage life of rabbiteye (*Vaccinium ashei* Reade) and northern highbush (*Vaccinium corymbosum* L.) blueberries has been studied extensively (Ballinger et al., 1978; Makus and Morris, 1993; Miller et al., 1988; Smittle and Miller, 1988). The southern highbush blueberry (*Vaccinium* spp.) is a hybrid derived largely from *V. corymbosum* and *V. darrowii* Camp. parentage and has a low chilling requirement and earlier ripening date than rabbiteye cultivars (Lyrene, 1990). Acreage planted in southern highbush blueberries is predicted to expand greatly by the year 2000 (Moore, 1993).

The storage life of rabbiteye blueberry fruit is reported to be superior to that of northern highbush fruit due to less fungal decay (Makus and Morris, 1993). However, only a few southern highbush blueberry cultivars have been studied for fruit quality. Miller et al. (1993) found that southern highbush 'Sharpblue' fruit softened more rapidly than 'Climax' rabbiteye fruit during storage. Lang and Tao (1992) reported that stored southern highbush fruit of 'Gulfcoast' was of lower quality than 'Sharpblue'. Although 'Sharpblue' acreage is currently the largest in the world, this cultivar has stem scar tearing, and corolla and pedicel adhesion, making it a poor quality cultivar in areas without early markets. Additionally, other low-chill cultivars are needed to diversify blueberry acreage.

With the predicted expansion of southern highbush blueberry plantings, evaluation of fruit from new southern highbush germplasm is needed. The purpose of this experiment was to evaluate the berry quality and shelflife of 'Sierra' and five southern highbush clones and compare these with two commercially important rabbiteye cultivars, 'Tifblue' and 'Climax'.

Materials and Methods

Blueberry fruit were harvested from the southern highbush cultivars 'Cape Fear', 'Cooper', Gulfcoast', 'O'Neal', and the breeding selection MS108 in 1993 and 1994. 'Sierra', which was released as a northern highbush cultivar, but includes several southern *Vaccinium* spp. in its parentage, was included. The rabbiteye cultivars 'Climax' and 'Tifblue' were used as standards. 'Sharpblue' does not consistently fruit in Arkansas and was not used in this experiment. Established plants used for harvests were not sprayed with fungicides

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from bloom through fruit ripening and were grown at the University of Arkansas Clarksville Fruit Substation, Clarksville, Ark. Bushes were harvested when at least 30% of fruit were ripe. Because of the short (2-4 weeks) fruiting season at this location, each clone was harvested twice at weekly intervals and results averaged for the harvest dates.

Harvested fruit, consisting of 3 to 4 liters per clone, were held in pulp boxes at 7-10C and transported to Lane, Okla. within 5 hr of harvest. Fruit were sorted to eliminate overripe, injured, or immature berries. A total of 6 replicates, three per harvest date, were used for each clone. A replicate consisted of a 250 ml pulp box containing 40 to 90 fruit, and covered with a cellulose acetate wrap. Fruit were held at 5C, 90% RH for 21 days then held one day at 20C, 80% RH to test fruit response under simulated transit and retail conditions.

In 1993, each box of fruit was generally rated for pedicel adherence ('stemming') and stem scar tearing. In 1994 the percentage of stemming and stem scar tearing was determined individually on a total of 200 fruit per cultivar. Stem scar tears were rated as small (<1mm), medium (1-2mm) and large (>2mm). Before storage, a total of 40 fruit per clone were weighed individually to determine berry size, and stem scar diameter at the widest point was measured to 0.01 mm using a dissecting microscope. Fruit were rated for the presence and severity of fungal decay after storage, where 1=no decay and 9=80-100% decay, and for softness, where 1=firm and 9=mushy. Weight loss was determined after storage at 5C and 20C.

Fruit composition, consisting of percent soluble solids concentration (SSC), titratable acidity (TA), and total anthocyanin content, was determined with frozen fruit using the method of Sapers et al. (1984). To determine average cultivar performance, means were averaged over years of harvest.

Results and Discussion

In 1993, 10 to 20% of 'Gulfcoast', 'Cooper', 'Cape Fear', and MS 108 berries were estimated to have attached pedicels (data not shown). More precise measurements in 1994 indicated that 'Cooper' and 'Gulfcoast' fruit had 20 to 30% stemming (Table 1). The large number of attached pedicels means a lower fruit pack grade (USDA, 1966) and expensive and laborious removal of pedicels to avoid rejection of the fruit pack.

Table 1. Characteristics of blueberry fruit harvested in 1993 and 1994 before storage[z].

Clone	Pedicel adherence[y]	Stem scar tears[y] %	Tear size[y]	Fruit weight (g/berry)	Stem scar diam (mm)	Ratio weight scar (g/mm)
Cape Fear	9	27	M	1.8	1.8	1.0
Cooper	22	33	L	1.6	2.1	0.8
Gulfcoast	33	40	L	1.6	2.1	0.8
MS108	3	26	M	1.5	2.2	0.7
O'Neal	0	10	S	2.1	1.5	1.4
Sierra	2	6	S	1.5	1.5	1.0
Climax	0	6	S	1.8	1.5	1.2
Tifblue	3	12	S	1.5	1.3	1.2
LSD	2	5	—	0.2	0.2	0.1

[z]Means separated within columns by LSD, P ≤ 0.05.
[y]Values are for 1994 only. Tear size: S = < 1 mm; M = 1-2 mm, L = > 2 mm.

Table 2. Characteristics and composition of blueberry fruit harvested in 1993 and 1994 after 21 days storage at 5C and 1 day at 20C.[z]

Clone	Weight loss (%)	Decayed fruit (%)	Soft fruit (%)	SSC (%)	TA (%)	SSC/ TA	Total anthocyanin (abs. units/g FW)[y]
Cape Fear	6.0	34	14	11.0	0.7	17.0	157
Cooper	7.5	37	28	12.5	0.8	9.9	108
Gulfcoast	8.4	38	27	10.2	0.8	12.9	106
MS108	6.8	33	30	10.6	1.1	9.8	62
O'Neal	6.1	19	4	12.9	0.6	22.0	112
Sierra	5.2	4	7	11.2	0.9	13.0	126
Climax	7.6	12	8	13.0	0.5	25.1	215
Tifblue	7.0	15	20	13.6	0.7	20.8	153
LSD	0.3	7	5	1.6	0.2	4.4	30

[z]Means separated within columns by LSD, P≤0.05.
[y]Absorbance at 520 nm per g fresh weight.

While stem scar tearing is usually associated with pedicel adherence, we found that many of the clones exhibited tearing, even when pedicels were absent (Table 1). However, the tear size appeared to correspond to the degree of pedicel adherence. 'Cooper' and 'Gulfcoast', the cultivars with the most stemming, were the only clones having large stem scar tears. Lang and Tao (1992) also reported stem scar tearing in 'Gulfcoast'. Clones exhibiting no stemming had small tears. The southern highbush cultivars 'Sierra' and 'O'Neal' had very little tearing, as did the rabbiteyes 'Climax' and 'Tifblue' (Table 1).

The southern highbush clones in this study varied in fruit weight and stem scar size, similar to that reported for rabbiteye and northern highbush fruit (Makus and Morris 1993). Stem scar diameter varied as much as 50% among southern highbush clones (Table 1). Large fruit did not necessarily have large stem scar diameters. To more easily compare fruit weights and stem scar diameters among clones, a ratio of berry weight to stem scar diameter was calculated, where a larger value was more desirable than a smaller value. 'Cooper', 'Gulfcoast' and MS108 had the lowest and 'O'Neal' fruit the highest ratio.

'Gulfcoast' had the most and 'Sierra' the least weight loss among all clones following storage (Table 2). Except for 'Gulfcoast', weight loss among the southern highbush clones was similar to or less than that of 'Tifblue' or 'Climax'.

Decay incidence was slight on 'Sierra' fruit (Table 2). Most of the southern highbush clones had 20-30% decayed fruit, while 'Climax' and 'Tifblue' had about 15% decay. For all clones, decay usually occurred on the stem end and covered 10-20% of berry surface area (data not shown).

The percent of fruit rated soft was about 30% for 'Cooper', 'Gulfcoast' and 'MS108' and less than 10% for 'O'Neal', 'Sierra', and 'Climax' (Table 2). Percent SSC generally did not differ between stored and fresh fruit. The rabbiteye cultivars and 'O'Neal' had a SSC exceeding 12%.

Titratable acidity ranged from 0.5 to 1.1% among clones (Table 2). Most of the southern highbush fruit, excluding 'O'Neal', had an SSC/TA ratio of less than 18, which is recommended for longest storage life (Galletta et al.,1971). The high SSC/TA value found for 'Climax' fruit is similar to other values reported for this cultivar (Makus and Morris, 1993; Smittle and Miller, 1988).

Among the southern highbush clones, 'Cape Fear' fruit were highest and MS108 fruit lowest in anthocyanin content

(Table 2). 'Climax' fruit had the most anthocyanins of all clones in this study. In summary 'Sierra' was comparable in quality to the commercially important rabbiteyes 'Climax' and 'Tifblue'. In this study, 'Cooper' and 'Gulfcoast' fruit were considered to be of poor quality before and after storage, with large stem scars, and high percentages of pedicel adherence, and decay.

Literature Cited

Ballinger, W. E., E. P. Maness and W. F. McClure. 1978. Relationship of stage of ripeness and holding temperature to decay development of blueberries. J. Amer. Soc. Hort. Sci. 103:130-134.

Galletta, G. J., W. E. Ballinger, R. J. Monroe and L. J. Kushman. 1971. Relationships between fruit acidity and soluble solids levels of highbush blueberry clones and fruit keeping quality. J. Amer. Soc. Hort. Sci. 96:758-762.

Lang, G. A. and J. Tao. 1992. Postharvest performance of southern highbush blueberry fruit. HortTechnology 2:366-369.

Lyrene, P. M. 1990. Low-chill highbush blueberries. Fruit Var. J. 44:82-86.

Makus, D. J. and J. R. Morris. 1993. A comparison of fruit of highbush and rabbiteye blueberry cultivars. J. Food Qual. 16:417-428.

Miller, W. R., R. E. McDonald and T.E. Crocker. 1988. Fruit quality of rabbiteye blueberries as influenced by weekly harvests, cultivars, and storage duration. HortScience 23:182-184.

Miller, W. R., R. E. McDonald and T. E. Crocker. 1993. Quality of two Florida blueberry cultivars after packaging and storage. HortScience 28:144-147.

Moore, J. N. 1993. The blueberry industry of North America. Acta Hort. 346:15-26.

Sapers, G. M., A. M. Burgher, J. G. Phillips, S. B. Jones and E. G. Stone. 1984. Color and composition of highbush blueberry cultivars. J. Amer. Soc. Hort. Sci. 109:105-111.

Smittle, D. A. and W. R. Miller. 1988. Rabbiteye blueberry storage life and fruit quality in controlled atmospheres and air storage. J. Amer. Soc. Hort. Sci. 113:723-728.

USDA. 1966. United States standards for grades of blueberries. 1966. USDA-AMS, Washington, D.C.

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TOLERANCE OF SNAP BEANS TO ELEVATED CO_2 LEVELS

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Abstract. **Elevated CO_2 levels have been reported to inhibit browning of snap beans at sites of mechanical injury. 'Strike' and 'Opus' snap beans were stored for up to 21 days at 1, 4 or 8C in controlled atmospheres with 2% O_2 plus up to 40% CO_2, then transferred to air at 20C for up to 4 days. Levels of CO_2 of 20% or greater always caused severe injury, manifested as loss of tissue integrity followed by decay. At 1C, 8% CO_2 was the maximum level tolerated; 18% CO_2 caused injury at 4C, but not at 8C. These results indicate that snap beans may be held for up to 3 weeks in 8 to 18% CO_2, depending on the temperature.**

Florida is the largest snap bean producing state in the United States, with about 30,000 acres grown, and a value of about $75 million (Fla. Agric. Stat. Serv., 1993). Florida supplies almost 50% of the total U.S. crop. Consumption of processed snap beans has decreased in recent years while that of fresh snap beans has increased (Judge and Sons, 1989, cited in Trail et al., 1992). This fact enhances the importance of postharvest handling for snap beans. Snap beans are very perishable, with a high respiration rate averaging about 200 ml CO_2/kg/hr at 25C (Parker and Stuart, 1935; Watada and Morris, 1966 b). Delays in handling and transport should be kept to a minimum.

With the use of mechanical harvesting, the number of beans with bruises and with broken ends has increased significantly (Isenberg, 1979). These damaged areas often develop brown discoloration within a few hours, when, for instance, they are being transported or held at temperatures as high as 27°C. This is a particularly important problem with snap beans for processing, which may be held for 48 hours at ambient temperatures prior to processing (Freeman and Sistrunk, 1978). Fresh market snap beans are also sometimes shipped by air under ambient conditions such as those exported from Florida to Europe. Exporting snap beans from Florida using marine shipment in containers capable of maintaining controlled atmospheres could be a less expensive alternative to air shipment.

Discoloration of snap beans at injury sites was reduced by storage in 20% CO_2 at 27C, compared to pods held in air, and almost completely prevented by storage in 30% CO_2 for 24 hours (Henderson and Buescher, 1977). Henderson et al. (1977) studied the role of phenolic content and phenolase activity in the postharvest discoloration of broken snap bean pods. They measured their levels in broken pods, which discolored in 24 hours, and in broken pods that were held in elevated CO_2 atmospheres. Discoloration was associated with increased levels of soluble phenolic compounds rather than increased enzyme activity. They concluded that control of discoloration by CO_2 was the result of inhibition of phenolic synthesis. The value of controlled atmospheres for storing green beans prior to marketing of the fresh product was studied by Groeschel et al. (1966). They concluded that in order to reduce the respiration rate by 40%, the O_2 level had to be reduced to 2%. Carbon dioxide had little or no effect on respiration, but losses in green color were minimized with the use of controlled atmospheres including 10% CO_2 because chlorophyll breakdown was retarded.

Snap beans are chilling sensitive, with injury reported by various authors to occur at temperatures as high as 4 to 7C (Gorini et al., 1974; Watada and Morris, 1966a; Groeschl et al., 1966), and cultivars differ significantly in their sensitivity to chilling injury (Watada and Morris, 1966b). Chilled beans

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