HortScience 19(5): 638–640. 1984.

Effect of Package Type and Storage Time-temperature on Weight Loss, Firmness, and Spoilage of Rabbiteye Blueberries

W.R. Miller, R.E. McDonald, C.F. Melvin, and K.A. Munroe
U.S. Department of Agriculture, Agricultural Research Service, 2120 Camden Road, Orlando, FL 32803

Additional index words. marketing, export, consumer packaging, *Vaccinium ashei*

Abstract. **Rabbiteye blueberries, *Vaccinium ashei* (Reade), were stored in each of 3 containers and 4 time-temperature regimes: 24 hr at 1°C + 24 hr at 10° + 24 hr at 21°; 48 hr at 10° + 24 hr at 21°; 7 days at 1°; and 14 days at 1°. Berries of 'Tifblue' lost less weight, were firmer, had fewer "leakers" and less decay than those of 'Woodard' following storage under identical treatments and storage conditions. When means of both cultivars and 4 time-temperature treatments were combined, there was an effect of consumer packaging type on weight loss, but there was no effect on berry firmness or the incidence of "leakers" and decay. There was no effect of packaging type on the percentage of sugars during 1 and 2 weeks of storage at 1°.**

The commercial blueberry (rabbiteye) industry in south Georgia is relatively young but is developing rapidly. Austin and Williamson (2) estimated in 1976 that total acreage in blueberry production in Georgia ranged from 240 to 325 ha; about 150 ha were plantings of less than 3 years old. In 1982, M.E. Smith (personal communication) of the Georgia Blueberry Association estimated acreage at about 810 ha with about one-half less than 3 years old. For fresh berries produced in Georgia, the principal market is in the southeastern states; however, the market area is expanding due to the aggressive efforts of industry leaders. During the 1983 season, the 1st Georgia berries were shipped successfully via air freight to western Europe. The rabbiteye blueberry (*Vaccinium ashei*) cultivars grown in the southeastern United States produce fruit that have a relatively tough protective skin, a small, dry stem scar, and they are relatively disease free (1, 6). Because the rabbiteye blueberry is known for good keeping quality during storage and for relatively early harvests due to geographic location, it is an attractive source of supply for the European market.

Although considerable information on fresh high-bush cultivars is available (3, 4, 5, 7, 8, 9, 13, 14, 15), relatively little information is available on the postharvest keeping quality of rabbiteye blueberries (10). No known studies related to shipping of rabbiteyes to European export markets via air freight are available. This study was designed to determine the comparative keeping quality of 2 major rabbiteye cultivars grown in Georgia. These cultivars were packaged in different consumer packs, and held under simulated air and surface transport time-temperature environments in order to provide information to shippers and exporters on the potential of shipping rabbiteyes to distant export markets.

Rabbiteye blueberries were obtained from the Georgia Blueberry Association packinghouse, Alma, Ga. Three separate tests (replicates) were conducted with, 'Woodard' and 'Tifblue', during June and July 1983. All beries were hand harvested and obtained ungraded either on the day of harvest or one day after harvest. In each test, all berries were from the same plantation and were brought to the USDA Laboratory at Orlando, Fla., for preparation and storage. Berries were not washed or treated with a fungicide prior to storage. In preparing berries for treatment lots, only those which were firm, mature blue in color, free of visual physical damage and of commercial size were used. In each test, a sample of three 0.47-liter units (one U.S. pint) for each of 3 different packaging treatments were held at each of the 4 different time-temperature regimes. The 3 packaging methods were: PAK 1) conventional pulp container (one U.S. pint) and plastic film cover secured in place with rubber band; PAK 2) polystyrene plastic container (one U.S. pint) with polystyrene plastic cover; and PAK 3) conventional pulp container completely enclosed with a copolymer heat-shrinkable plastic film (Clysar EHC 50, DuPont). The physical properties for this film are as given by Hale et al. (11). The film was wrapped around each filled container and sealed with a hot-wire sealer (Weldotron Corp., model 6001), and containers were conveyed through a heat tunnel (Weldotron Corp., model 7001). Although the film shrank tightly around the filled container, it was not airtight because small, pin-sized holes developed near the hot-wire seal during the shrinking process.

The 4 time-temperature storage treatments were: TRT 1) 24 hr at 1°C plus 24 hr at 10° plus 24 hr at 21°; TRT 2) 48 hr at 10° plus 24 hr at 21°; TRT 3) 7 days at 1°; and TRT 4) 14 days at 1°. TRT's 1 and 2 simulated expected environments during precooling and air freight shipping to the European market, and TRT's 3 and 4 simulated expected environments during prolonged term surface shipment via sea transport. Because the main objective was to determine the package effect on berries at each time-temperature treatment for each cultivar, all evaluations were made immediately following each initial time-temperature regime, without an additional simulated marketing time. The film wrapping of package type 3 was destroyed at the time of berry evaluation.

Before storage, each container was filled full with berries, and each was identified and weighed. Following storage, each container was reweighed, and each berry was individually rated for firmness, shrivelling, leakage, and decay. Firmness was determined subjectively by applying light finger pressure while rotating the berry between the thumb and index finger. Scoring for firmness was either soft or firm; soft = yield to applied finger pressure; and firm = no yield to finger pressure. Shrivelling, leakage, and decay were determined by visual observation. "Leakers" were categorized as decay.

From each test prior to storage, samples were taken at random for measurement of glucose, fructose, and sucrose by high-pressure liquid chromatography (12). Sugar analyses also were taken from berries stored for 7 and 14 days (TRT's 3 and 4).

All consumer units tested were placed in commercial shipping containers and then into refrigerated storage. Temperatures were maintained ± 1.0°C of setpoint, and relative humidity ranged from 88% to 95%.

Data for weight loss, firmness, and decay were averaged across package types (PAK) and storage treatments (TRT) by cultivar and were analyzed by analysis of variance procedures. There was significantly more weight loss, fewer firm berries and more decay with 'Woodard' compared to 'Tifblue' (Table 1). There was significantly less weight loss for berries held in PAK 3 for both cultivars than when stored in PAK 1 and PAK 2. For 'Woodard' there was a difference in weight loss among each PAK tested. Package type had no effect on berry firmness and decay.

There was no difference in weight loss between TRT's 1 and 2 for 'Woodard' or 'Tifblue'. A difference between TRT's 3 and 4 for 'Woodard' is statistically significant but of little practical importance, and there was no difference between TRT's 3 and 4 for 'Tifblue'.

For 'Woodard', TRT 2 resulted in the least percentage of firm berries but was not statistically different from TRT 1; whereas, for 'Tifblue', TRT 2 gave the greatest percent-

Received for publication 10 Dec. 1983. Use of a company or product name by the USDA does not imply approval or recommendation of the product to the exclusion of others which may also be suitable. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

Table 1. Effects of packaging (PAK) and time-temperature treatments (TRT) on quality and spoilage of 'Tifblue' and 'Woodard' blueberries.

Description of variables	No. berries per PAK $\bar{x}$	Wt loss (%)	Firm berries (%)	Decay[z] (%)
Cultivar (CV)				
Woodard	243	0.53 a[y]	65.8 a	1.45 a
Tifblue	260	0.39 b	84.2 b	0.12 b
Package type (PAK) × cultivar				
Woodard				
PAK 1	244	0.89 a	66.0 a	1.45 a
PAK 2	238	0.63 b	67.8 a	1.30 a
PAK 3	246	0.08 c	63.6 a	1.59 a
Tifblue				
PAK 1	263	0.52 a	83.3 a	0.11 a
PAK 2	256	0.52 a	86.1 a	0.12 a
PAK 3	261	0.13 b	82.3 a	0.13 a
Storage treatment (TRT) × cultivar				
Woodard				
TRT 1	247	0.63 a	63.5 ab	1.54 a
TRT 2	235	0.63 a	57.7 a	2.98 b
TRT 3	244	0.32 b	72.8 c	0.54 a
TRT 4	244	0.55 a	69.1 bc	0.72 a
Tifblue				
TRT 1	255	0.21 a	83.0 ab	0.22 a
TRT 2	272	0.24 a	89.6 b	0.11 a
TRT 3	258	0.44 ab	86.4 b	0.07 a
TRT 4	254	0.67 b	77.9 a	0.08 a
Statistical significance[x]				
CV		**	**	**
PAK		**	NS	NS
TRT		**	v	**
CV × PAK		**	NS	NS
CV × TRT		**	**	**
TRT × PAK[w]		*	NS	NS

[z]Includes decay and "leakers".
[y]Values in column followed by the same letter are not significantly different by Duncan's multiple range test, 5% level. Comparisons of treatments and package type are within a cultivar.
[x]Nonsignificant (NS), or significant at 5% (**) or 1% (*) level by factorial effect analyses.
[w]For interaction see Table 2.
[v]Significant at the 7% level.

age of firm berries but was not statistically different from TRT's 1 and 3. The relative magnitude of this difference between the 2 cultivars in berry firmness in response to TRT 2 is unexplainable; however, this difference was consistently expressed among replications (the incidence of firm berries for TRT 2 ranged from 57.4% to 58.0% and 89.1% to 90.7% for 'Woodard' and 'Tifblue', respectively). The average effect of TRT 2 in 'Woodard' resulted in significantly more decay than for other storage treatments, whereas there was no difference in amount of decay by treatments for 'Tifblue'.

Complete data for the packaging type and storage treatment effect on weight loss by cultivar are depicted in Table 2. Use of package type 3 generally resulted in less weight loss than for PAK's 1 and 2 for each storage treatment and each cultivar, and, consequently, PAK 3 gave significantly reduced weight loss at each treatment when averaged over both cultivars.

Weight loss is relatively low, less than 1%, for most PAK-TRT combinations. These weight loss results are consistent with previous findings which showed that blueberries lose about 1% moisture per week when stored in uncovered containers and lose about 0.3% per wk when stored in plastic lined containers at about 1°C (10, 13).

The sugars found in these blueberries were glucose and fructose (3, 14), and only a small amount of sucrose was detected. There was no cultivar effect on sugar content. Results therefore were combined and analyzed by package type only. The type of package also had no effect on sugar content after storage for 1 and 2 weeks (complete data not presented). As expected, glucose and fructose concentrations decreased with time in storage.

Shippers using air freight requiring a relatively short transit time of 3 days or less may expect less than 1% weight loss at time of delivery by precooling berries to either 1° or 10°C. Similarly, precooling berries to about 1° and properly maintaining temperature during 1- and 2-week surface transport should keep weight loss to about 1% or less. Completely overwrapping consumer units in plastic film gave the least weight loss compared to other package types tested. In addition to maintaining good fruit condition, controlling weight loss is advantageous when shipping berries to markets that require a guaranteed consumer unit net weight on delivery.

Shippers engaged in exporting to distant markets can deliver a high-quality product by requesting growers to supply berries of cultivars that have superior keeping quality and by maintaining proper storage and transit temperatures. Decay was relatively low for both cultivars, but 'Tifblue' had about 11 times less decay than 'Woodard' following all storage treatments. 'Tifblue' had considerably less decay than 'Woodard' following simulated air shipment storage (TRT's 1, 2), suggesting that 'Tifblue' may deteriorate more slowly than 'Woodard' during short transit times via air when proper temperatures usually are not maintained. During storage of 1 and 2 weeks, when berries were held constantly at 1°C, decay was less than 1% for 'Woodard' or about 7 times greater than decay for 'Tifblue'. Berry shrivelling was not a problem in either cultivar because of low moisture loss during storage, but 'Tifblue' had a higher percentage of firm fruit following all storage treatments than 'Woodard'. Since weight loss was generally less than 1% for all package types during storage treatments, shippers should base their use of packaging type on practical preferences at their packing facility, cost of materials and customer preferences within particular market areas. With careful cultivar selection, proper precooling, packaging, and maintenance of transit temperature, shippers should be able to export rabbiteye blueberries successfully to distant markets via air or sea transport.

Table 2. Effect of packaging (PAK) on weight loss by cultivar and time-temperature treatments (TRT).

Cultivar and package type	Treatment TRT 1	TRT 2	TRT 3	TRT 4
'Woodard'				
PAK 1	1.11 a[z]	1.08 a	0.45 a	0.92 a
PAK 2	0.61 ab	0.68 a	0.51 a	0.70 a
PAK 3	0.17 b	0.12 b	0.01 b	0.04 b
'Tifblue'				
PAK 1	0.16 a	0.21 a	0.57 a	1.12 a
PAK 2	0.39 b	0.33 a	0.55 a	0.81 b
PAK 3	0.08 c	0.17 a	0.19 b	0.09 c
$\bar{X}$ of both				
PAK 1	0.64 a[z]	0.65 a	0.51 a	1.02 a
PAK 2	0.50 a	0.51 a	0.53 a	0.76 b
PAK 3	0.12 b	0.15 b	0.10 b	0.06 c

[z]Values in column within cultivar group followed by the same letter are not significantly different by Duncan's multiple range test at 5%.

Literature Cited

1. Austin, M.E. 1978. Difolatan effects on shelf life of rabbiteye blueberries. Fruit South 62–65.
2. Austin, M.E. and R.E. Williamson. 1977. Comparison of harvest methods of rabbiteye blueberries. J. Amer. Soc. Hort. Sci. 102(4):454–456.
3. Ballinger, W.E. and L.J. Kushman. 1970. Relationship of stage of ripeness to composition and keeping quality of highbush blue-

berries. J. Amer. Soc. Hort. Sci. 95(2):239–242.
4. Ballinger, W.E., L.J. Kushman, and D.D. Hamann. 1973. Factors affecting the firmness of highbush blueberries. J. Amer. Soc. Hort. Sci. 98(6):583–587.
5. 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(1):130–134.
6. Brightwell, W.T. and M.E. Austin. 1980. Rabbiteye blueberries. Univ. Georgia Res. Bul. 259.
7. Cappellini, R.A. and M.J. Ceponis. 1977. Vulnerability of stem-end scars of blueberry fruits to postharvest decays. Phytopathology 67:118–119.
8. Cappellini, R.A., M.J. Ceponis, and C.P. Schulze. 1983. The influence of "sweating" on postharvest decay of blueberries. Plant Disease 67:381–382.
9. Ceponis, M.J. and R.A. Cappellini. 1979. Control of postharvest decays of blueberry fruit by precooling, fungicide, and modified atmosphere. Plant Dis. Rptr. 63:1049–1053.
10. Dekazos, E.D. and C.J.B. Smit. 1976. Effect of variety, packaging and storage conditions on the shelf life and quality of rabbiteye blueberries. Ga. Agr. Res. 18:19–23.
11. Hale, P.W., P.L. Davis, F.J. Marousky, and A.J. Bongers. 1982. Evaluation of a heat-shrinkable polymer film to maintain quality of Florida grapefruit during export. Citrus & Veg. Mag. 46:39–48.
12. Miller, W.R., P.W. Hale, D.H. Spalding, and P. Davis. 1983. Quality and decay of mango fruit wrapped in heat-shrinkable film. HortScience 18(6):957–958.
13. Hruschka, H.W. and L.J. Kushman. 1963. Storage and shelf life of packaged blueberries. USDA, Agr. Res. Ser., Mkt. Rev. Rpt. No. 612.
14. Hudson, D.E. and W.H. Tietjen. 1981. Effect of cooling rate on shelf life and decay of highbush blueberries. HortScience 16(5):656–657.
15. Woodruff, R.E., D.H. Dewey, and H.M. Sell. 1960. Chemical changes in 'Jersey' and 'Rubel' blueberry fruit associated with ripening and deterioration. Proc. Amer. Soc. Hort. Sci. 75:387–401.

HortScience 19(5): 640–641. 1984.

Resistance of *Fragaria chiloensis* Clones to the Twospotted Spider Mite

Carl H. Shanks, Jr.
Washington State University, Southwestern Washington Research Unit, 1919 N.E. 78th Street, Vancouver, WA 98665

Bruce H. Barritt
Tree Fruit Research Center, Washington State University, 1100 North Western Avenue, Wenatchee, WA 98801

Additional index words fruit breeding, strawberry, host plant resistance, *Tetranychus urticae*

Abstract. **Thirty clones of the beach strawberry, *Fragaria chiloensis* (L.) Duch., that were known to be resistant to strawberry aphid, *Chaetosiphon fragaefolii* (Cockerell), were evaluated for resistance to twospotted spider mite, *Tetranychus urticae* Koch. All clones had fewer mites per leaf than the cultivar 'Totem'. Two clones, BSP-14 and LCM-19, had totals of only 6 and 82 mites, respectively, on 4 dates compared to 1741 mites on 'Totem'. The 'Del Norte' clone of *F. chiloensis*, previously used as a source of aphid resistance in breeding, was more susceptible than BSP-14 and LCM-19 to the mite.**

Resistance to twospotted spider mite (TSSM), *Tetranychus urticae* Koch, has been bred into clones of the cultivated strawberry, *Fragaria* ×*ananassa* Duch. (1, 5, 6), but most clones of this species are highly susceptible to the strawberry aphid, *Chaetosiphon fragaefolii* (Cockerell) (2, 4). Crock et al. (2) identified 29 clones of the wild beach strawberry, *F. chiloensis* (L.) Duch., with resistance to the strawberry aphid similar to that of *F. chiloensis* 'Del Norte' (4). These 30 clones were evaluated in the present study for resistance to TSSM to determine if clones with a high level of resistance to both pests could be found.

Potted plants were grown in a greenhouse during the entire year without supplemental light or heat. Fans drew in outside air whenever the inside temperature rose to 5° to 7°C. The plants were 2 years old when evaluated. Plants of *F.* ×*ananassa* cultivar 'Totem' were included as a known TSSM-susceptible cultivar. Clones were tested for resistance to TSSM using 6 plants per clone in a completely randomized design. Plants became infested naturally with TSSM from the greenhouse population.

Mites were counted on 4 dates from 22 Apr. – 7 June, at which time TSSM populations are always highest on strawberries in western Washington. One leaflet was removed from each of 3 mature leaves on each plant. On each date, the mean number of mites per 3 leaflets was determined first for 'Totem'. On the *F. chiloensis* plants, the actual number of mites on the 3 leaflets of each plant were counted. If that number was greater than 25% of the 'Totem' population, only the number that represented 25% of the population on 'Totem' was recorded along with a plus sign (+). Clones were scored on each date by assessing one point for each plant that had a mite population greater than 25% of the population on 'Totem'. The highest score for a clone on any date was 6, meaning that every plant had more than 25% of the TSSM population on 'Totem' on that date.

All plants of 2 *F. chiloensis* clones, BSP-14 and LCM-19, always had fewer than 25% of the mite number found on 'Totem' on each date and therefore had a total score of zero (Table 1). The total number of mites counted on these clones on all 4 dates was only 6 and 82, respectively, compared to 1751 on 'Totem'. Seven clones had scores of only 1, and 6 clones had scores of only 2 out of a possible total score of 24 for all 4 dates.

For strawberry breeding programs, *F. chiloensis* clones BSP-14, LCM-19, and RCP-37 seem to be excellent sources of resistance to both TSSM and the strawberry aphid. BSP-14 and LCM-19 were collected on the Oregon coast at Bandon State Park and Lincoln City, respectively, (2) and RCP-37 was collected at Redwood Creek Park on the north California coast (3).

'Del Norte', which is the source of resistance to strawberry aphid in our breeding program, was less susceptible to TSSM than 'Totem' but was the 2nd most susceptible *F. chiloensis* clone in this test. In previous work, when 'Del Norte' was crossed with 'Olympus' and WSU 1019, some very resistant progeny were produced (6). 'Olympus' and WSU 1019 have moderate levels of resistance to spider mites (6), however, so the progeny resistance could not all be attributed to 'Del Norte'. We have observed large numbers of TSSM on 'Del Norte' at other times. More work is needed to determine whether 'Del Norte' is a useful source of resistance to TSSM.

Received for publication 2 Apr 1984. Scientific Paper No. 6784, Washington State Univ., College of Agr. Res. Ctr., Pullman 99164. Projects no. 1957 and 0038. Partially supported by a grant from the Oregon Strawberry Commission. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.