Influence of Water Immersion Time and Storage Period on Black Rot Development in Cold-Stored, Water-Harvested Cranberries

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ABSTRACT

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Water-harvested and dry-harvested Early Black cranberries (*Vaccinium macrocarpon*) were subjected to several harvest water-immersion times, stored for up to 10 wk at 3.5 C, and evaluated for fungal decay. The longer detached cranberry fruit was left in the bog water, the greater was the amount of black rot in stored fruit. As storage period increased from 2 to 10 wk, black rot incidence increased. Black rot caused by *Strasseria oxycocci* and *Ceuthospora lunata* occurred in 68% of the fungus-decayed fruit, with the former causing about seven times more black rot than the latter. The failure of current fruit-rot fungicide control programs to control black rot creates a problem in the storage and fresh-market sale of water-harvested cranberries.

New Jersey is an important producer of cranberries (*Vaccinium macrocarpon* Ait.), most of which are water-harvested and processed. The berries are stripped from their vines in flooded bogs by motorized, rotating water reels. The freed berries are then removed from the water by conveyor belts. Berries may float in the water for several days, but usually they stay in the water less than 18 hr. Because water-harvested cranberries from New Jersey deteriorate rapidly in cold storage, their potential for the fresh market is very limited (M. Ceponis, *unpublished*). Wisconsin growers recognized early the economic benefits of water-harvesting and adapted this harvest method for the fresh market. Stevens and Bergman (12) found that losses in marketing channels were greater for water-raked than for dry-raked Wisconsin-grown cranberries.

As far as we know, there is no recent report of postharvest disease development in the cold storage of water-harvested cranberries. In New Jersey, the feasibility of fresh-marketing water-harvested cranberries depends partly on minimizing the incidence of cranberry rot in storage and marketing channels. This study was conducted, therefore, to determine the principal cause or causes of fungal deterioration and the influence of water immersion time and storage period on the fungal-induced decay of water-harvested New Jersey cranberries. A preliminary report of a portion of this study has been published (13).

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MATERIALS AND METHODS

Early Black cranberries were gathered at various times during the harvesting seasons of 1976–1979. The berries were water-harvested from their vines by a motorized water reel; a sample was removed immediately after the water reel operation and again after the fruit had floated in the water for 4, 8, 12, or 24 hr. Dry-harvested berries, either hand-picked or hand-raked, were dumped into the bog water at the start of the water reel operation with the exception of the zero-time sample, which was not wetted. After removal from the bog water, the berries were washed with tap water, dried by forced warm air (as is done commercially), and culled to remove the obviously damaged and decayed fruit. The remaining sound fruit was stored at 3.5 C in open-mesh plastic pint (473 ml) containers. The fruit was removed from storage after 2, 4, 6, 8, and 10 wk and examined for fungal decay after the berries were held an additional 4 days at 21 C. A total of six replicate pints were examined for each treatment in each test.

Fungal decays were identified either by symptom expression or by culturing rotted tissue on potato-dextrose or V-8 juice agar. Black rot was identified by visual examination of the fruit. In 1979, workers in Wisconsin discovered that *Strasseria oxycocci* Shear caused fruit symptoms very closely resembling the black rot caused by *Ceuthospora lunata* Shear (6). All fungal decays were cultured in 1979 to identify the prevalence of *S. oxycocci.*

RESULTS

Increasing the water immersion time of cranberry fruit from 0 to 12 or 24 hr caused a significant increase in fungal rots (Table 1). Black rot comprised 60–76% of the total decays, and this percentage was affected very little by water immersion time. At all water immersion times, the water-harvested berries had more decay than the dry-harvested fruit.

Black rot and total fungal rot were significantly increased by holding the cranberries in cold storage longer (Table 2). Black rot was not evident as a major fungal decay until the fourth week of storage. The wet-harvested berries were more adversely affected than the dry-harvested ones.

S. oxycocci caused approximately seven times more black rot than *C. lunata* (Table 3). Very little *C. lunata* was detected in dry-harvested fruit, but it occurred with greater frequency in wet-harvested fruit. In wet-harvested fruit, a steady increase in black rot caused by *S. oxycocci* was noted up to the 12-hr immersion period.

Physalospora vaccinii (Shear) Arx and Muller, *Penicillium* sp., and *Sporonema oxycocci* Shear caused most of the remaining fungal rot. *Guignardia vaccinii* Shear, *Glomerella cingulata* (Ston.) Spauld. & Schrenk var. *vaccinii* Shear, and *Godronia cassandrae* Pk. were infrequently isolated from decayed fruit in these tests.

DISCUSSION

Black rot was the principal fungal decay occurring in our tests on water-harvested, cold-stored cranberries in New Jersey. In Wisconsin, where cranberries are mainly water-harvested (3), black rot caused by *C. lunata* is now considered to be second only to end rot caused by *Godronia cassandrae* as a cause of storage rot.

Black rot incidence increased as water immersion time lengthened. This may be caused by longer exposure to waterborne inoculum. Schwarz and Boone (7) found that spores of *C. lunata*, incitant of black rot in Wisconsin, were present in the floodwater during harvest. Thus, the sooner berries are removed from the floodwater, and the shorter the exposure of the fruit to the inoculum, the less

Table 1. Effect of water immersion times at harvest on postharvest development of black rot and total fungal decay of cranberries in storage

Year	Method of harvest[w]	Water immersion time (hr) and rots (%)[x] 0 Black	0 Total	4 Black	4 Total	8 Black	8 Total	12 Black	12 Total	24 Black	24 Total
1976	Wet	2.0	3.1	1.5	2.6	1.4	2.8	1.7	3.6	1.7	3.2
1977	Dry	1.9	2.4	3.7	4.6	3.6	4.0	4.5	5.6	5.3	6.6
	Wet	3.6	5.1	4.4	6.2	4.4	6.2	4.5	6.6	5.1	7.2
1978	Dry	1.3	2.2	1.7	2.3	2.0	2.8	2.4	3.3	4.5	6.3
	Wet	2.5	4.3	3.4	6.0	3.9	7.7	4.3	8.6	4.8	9.7
1979	Dry	0.1	0.2	0.4	0.7	0.2	0.7	0.9	1.3	0.8	1.5
	Wet	2.5	4.0	3.9	6.0	5.1	7.7	5.5	8.1	4.8	7.6
1976–1979	Dry	1.1 a[y]	1.6 a	1.9	2.5 a	1.9 a	2.5 a	2.6 a	3.4 a	3.5 a	4.8 a
	Wet	2.6 b	4.1 b	3.3 b	5.2 b	3.7 b	6.1 b	4.0 b	6.7 b	4.1 b	6.9 b
All years	Wet + Dry	2.0	...	2.7 NS	...	2.9 NS	...	3.4*[z]	...	3.9*	...
	Wet + Dry	...	3.0	...	4.1 NS	...	4.6 NS	...	5.3*	...	5.0*

[w] Dry = hand-picked or hand-raked; wet = water-reel harvested.
[x] Values are combined means of all storage periods for all tests conducted in a given year or years; 802,071 fruits were examined.
[y] Means in same column followed by same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$).
[z] * Significantly different from zero-hour values for black rot and total rots, respectively, at the 5% level.

Table 2. Effect of storage period on incidence of black rot and total fungal decay in cranberries

Year	Method of harvest[w]	Storage period (wk) and rots (%)[x] 2 Black	2 Total	4 Black	4 Total	6 Black	6 Total	8 Black	8 Total	10 Black	10 Total
1976	Wet	0.2	1.5	1.0	2.1	2.7	3.7	2.6	3.9	...	...
1977	Dry	0.6	2.4	3.2	3.8	4.2	5.0	5.3	6.0	5.7	6.5
	Wet	1.2	3.8	4.0	5.4	4.8	6.4	5.6	7.1	6.4	8.5
1978	Dry	0.4	1.4	1.5	2.5	3.1	4.1	2.7	3.0	3.8	5.1
	Wet	1.2	3.1	3.7	5.3	4.8	7.8	7.0	9.2	5.2	8.5
1976–1978	Dry	0.5	1.9	2.4	3.2	3.6	4.6	4.0	4.5	4.8	5.8
	Wet	0.9	2.8	2.9	4.3	4.1	6.0	5.0	6.7	5.8	8.5
All years	Wet + Dry	0.7 a[y]	...	2.7 b	...	3.9 bc	...	4.6 c	...	5.3 c	...
	Wet + Dry	...	2.4	...	3.8*[z]	...	5.4*	...	5.8**	...	7.2**

[w] Dry = hand-picked or hand-raked; wet = water-reel harvested.
[x] Values are combined means for all water-immersion times for all tests conducted in a given year or years; 691,364 fruits were examined.
[y] Means in same row followed by same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$).
[z] * Significantly different at the 5% level; ** significantly different at the 1% level.

Table 3. Incidence of *Ceuthospora lunata* and *Strasseria oxycocci* in cold-stored cranberry fruit in 1979[x]

Immersion time (hr)	Black rot (%) *C. lunata* Dry[y]	*C. lunata* Wet	*S. oxycocci* Dry	*S. oxycocci* Wet	Total fungal rots Dry	Total fungal rots Wet
0	0.0 a[z]	0.5 a	0.1 a	2.0 a	0.2 a	4.0 a
4	0.0 a	0.6 a	0.3 a	3.3 b	0.7 a	6.0 b
8	0.1 a	0.9 a	0.2 a	4.3 c	0.7 a	7.7 c
12	0.1 a	0.5 a	0.8 b	5.0 c	1.3 b	8.1 c
24	0.1 a	0.3 a	0.8 b	4.4 c	1.5 b	7.6 c

[x] Values are combined means of all storage periods in 1979 tests; 24,000 fruits were examined.
[y] Method of harvest: dry = hand-picked; wet = water-reel harvested.
[z] Means in same column followed by same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$).

chance there will be for infection. Stevens and Bergman (12) emphasized the need to remove water-harvested fruit from the water as rapidly as possible and to dry them quickly to maintain fruit quality.

Bruising associated with the water-reel harvesting method, versus that resulting from hand-picked or hand-raked dry harvesting methods, may explain the greater amount of black rot and total fungal rot occurring in water-harvested fruit. Bruising has been shown to result in increased black rot development as well as other fungal-induced rots, although the sample size in those studies was quite small (5). Wounding, which can occur with water harvesting, has been shown to be a prerequisite to infection by *C. lunata* (7). Although we did not compare the hand-picked versus hand-raked methods, Shear et al (10) found little difference between the two methods on rot incidence in a 2-mo storage test on the Early Black cultivar. The low incidence of decay in the dry-harvested berries in 1979 may be attributed to the exceptional care taken in hand-picking and handling of the fruit.

The steady increase in fungal rots as storage time increased from 2 to 10 wk was probably the result of activation of latent infections in the fruit or of facultative fungi that advanced into the sound tissue from dead plant parts on the fruit as it matured in storage. Stevens (11) and Wilcox (14) have shown that some rot-producing fungi become established on or in the fruit early in fruit development; physiologic change in the fruit that occurs in storage must thus allow fungal decay to progress. Evidence that there is little or no spread of rot-causing fungi from fruit to fruit in storage is available (4). For latent and incipient black rot infections to become evident, a lengthy development period would be required at a storage temperature of 3.5 C. Whether black rot infections occur prior to or during water-harvesting needs further study. Schwarz and Boone (7) indicate that *C. lunata* infection does occur during the water-harvesting operation.

The discovery by Schwarz (6) that *S. oxycocci* was causing almost identical symptoms of black rot as those caused by *C. lunata* was based on culturing of fruit from New Jersey. *S. oxycocci* has not been found on cranberry fruit in Wisconsin (3,6). Shear (8) described *S. oxycocci* (*Plagiorhabdus oxycocci* Shear) as it occurred on cranberry leaves from

Massachusetts. He speculated that it would probably be found on cranberry fruit. More recently, Eglitis et al (2) reported *S. oxycocci* as being saprophytic on leaves of both cranberry and highbush blueberry, but no mention was made of its occurrence on fruit. *C. lunata*, the generally recognized incitant of black rot, has been reported in all the important cranberry-growing areas of the United States (9). Even though *C. lunata* is present in all five cranberry-producing states, it has been reported as important only in Oregon (9) and Wisconsin (3). Zuckerman (15) and Bergman and Wilcox (1) did not report either *C. lunata* or *S. oxycocci* in their studies of cranberry storage rot fungi in Massachusetts.

The low incidence of *G. vaccinii, Sporonema oxycocci, Glomerella cingulata, Physalospora vaccinii,* and other fungi in the stored cranberry fruit in our study resulted from an effective field fungicide program. Throughout the test period, captafol (4.6 kg a.i./ha, three applications during and after bloom) was used as a maintenance fungicide.

Black rot poses a serious problem for growers contemplating sale of water-harvested New Jersey cranberries on the fresh market. Current fungicide control programs are not effective in controlling black rot. Quick removal of water-harvested fruit from the flood water, rapid drying of the fruit, and avoidance of harvesting overmature fruit should reduce the incidence of black rot in the Early Black cultivar. Evaluation of other cranberry cultivars is needed to ascertain their susceptibility to black rot. A thorough understanding of the life history of the two fungi inciting black rot may also provide insights into practical control measures.

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