Effect of Air-Drying on Soft Rot Potential of Potato Tubers Inoculated by Immersion in Suspensions of *Erwinia carotovora*

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ABSTRACT

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Potato tubers were immersed for 5 min in suspensions of *Erwinia carotovora* pv. *carotovora* or pv. *atroseptica*, then incubated in a mist chamber for 72–96 hr. Disease severity decreased when tubers were air-dried before incubation and when the following types were used: 1) tubers fully cured rather than freshly harvested or injured, 2) tubers with bacteria only on their surfaces rather than infiltrated, or 3) tubers exposed to extended drying periods. In contrast, increasing the numbers of *E. carotovora* pv. *carotovora* ($\geq 5 \times 10^7$ colony-forming units per milliliter) in the inoculum decreased the effect of air-drying. An increase in the drying period from 1 or 2 to 69 hr or more also suppressed disease.

Bacterial soft rot is likely to occur if freshly harvested potato tubers (*Solanum tuberosum* L.) at 20 C are covered with a film of water ("wet") for 20–28 hr (4). Tubers dried within 16 hr of becoming wet usually remain free of decay. Ruehle (12) clearly demonstrated the value of drying tubers with heated air as a control for bacterial soft rot during commercial handling. Unfortunately, many packinghouses still have not adopted this practice.

Sponge rollers mounted in the packing line may remove enough water to minimize water films and the threat of bacterial soft rot. This procedure is effective if tubers are stored in a ventilated or refrigerated environment. When environmental conditions are unfavorable for drying, however, sponge rollers and ventilation may not remove residual free water. In addition, water is likely to condense on tubers stored in a humid environment if the air temperature increases even slightly above the tuber temperature (11).

Changes in soft rot potential (probability of bacterial soft rot if tubers become wet) that occur if wet tubers are dried have not been defined clearly (2–4,6,9). Lund and Kelman (9) reported that the soft rot potential of tubers sampled after passage through a commercial heated-air drier was similar to that of tubers sampled just before passage through the drier. Both samples, however, were transported to the laboratory (and air-dried) before being moistened and incubated in a mist chamber. On the other hand, less disease occurred when inoculated tubers were air-dried and held for 4 days in a humid room (≥90% RH) before mist-chamber incubation than when tubers were incubated immediately after inoculation (4).

Modern packinghouses are designed to handle large volumes of tubers efficiently. In many such facilities, large flumes of water transport tubers from storage bins and dump tanks to packing lines. In some instances, tubers are raised 4–5 m in a flume to the packing line level. The periodic high incidence of bacterial soft rot in potato shipments from these facilities has not only alarmed packinghouse managers but has also raised questions as to the effectiveness of standard commercial drying procedures. The objective of this study was to evaluate the effects of short-term air-drying treatments on the soft rot potential of freshly washed potato tubers.

MATERIALS AND METHODS

General procedures. Unwashed potato tubers were selected from commercial storage bins or harvested from commercial fields or experimental plots on sandy loam soils in central Wisconsin. Tubers 200–350 g (fresh weight) were selected for freedom from injury and disease.

Suspensions of *Erwinia carotovora* pv. *carotovora* (Ecc) or *E. carotovora* pv. *atroseptica* (Eca) were prepared from shake cultures as described previously (2). Unless indicated otherwise, the inoculum contained 5×10^6 colony-forming units (cfu) per milliliter.

Exposure of tubers to wash water as it could occur under commercial packinghouse conditions was simulated by submersion of tubers in water alone or water containing cells of soft rot *Erwinia*. The period of submersion was 5 min unless specified differently. Hydrostatic pressure on tuber surfaces was varied from about 5 to 530 cm of water by applying air pressure to tubers submerged in water in a 19-L pressure-cooker. In some tests, the pressure caused water and bacteria to infiltrate lenticels, based on a test treatment with dye solution or ink suspension on a sample of the tuber lot as described previously (4).

Wet tubers were dried on a wire-mesh rack in ambient laboratory air or in the airstream from an electric fan. Air temperatures ranged from 22 to 26 C and relative humidity was estimated at 40–70%. Tuber surfaces were completely free of visible moisture within about 45 or 90 min when dried with or without a fan, respectively.

Tubers were incubated in a mist chamber at 20 C, usually for 96 hr as described previously (2–4,9). Unless indicated otherwise, air-dried tubers were gently moistened with tap water at the onset of incubation so that all surfaces were uniformly wet. After incubation, the percentage of surface area decayed (disease severity) was rated by the Horsfall-Barratt system (5). These ratings were used in all statistical analyses, which were completed with the Statistical Analysis System (SAS Institute, Cary, NC) using the appropriate computer program (ANOVA or GLM).

A representative sample of 10 tubers from each lot was moistened with tap water and incubated with treated tubers to determine the base-level soft rot potential associated with previous inoculation, injury, and handling.

Experiments. *Surface-contaminated, cured tubers.* The soft rot potential of inoculated and air-dried potato tubers was first examined with commercially stored tubers (cultivar Russet Burbank stored about 5 mo) that were warmed to room temperature (22 C) before treatment. Thirty tubers were submerged in a suspension of Ecc and removed after 64 min. Ten were placed directly in the mist chamber and 20 were air-dried for 2 hr. Ten of these tubers were moistened with water and the other 10 were dry when placed in the mist chamber; the dry tubers became wet within 6 hr.

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Effects of the level of hydrostatic pressure, concentration of inoculum, and period of air-drying on disease were examined with a second sample of stored tubers. The factorial experimental design (10 tubers per treatment) included two hydrostatic pressures, two levels of inoculum, and three drying treatments, with or without moistening before incubation. Hydrostatic pressures of 180 or 530 cm were applied for 4 min to tubers submerged in 5×10^5 cfu per milliliter of Ecc or in tap water. A sample from this batch of tubers was not infiltrated when exposed to 530 cm of pressure for 4 min while submerged in a rhodamine dye solution (0.7 g/L).

Infiltrated, freshly harvested tubers. The soft rot potential of freshly harvested tubers (cultivar Superior) was examined in tests that included the possible interaction of drying with infiltration of lenticels with Ecc. Tubers were hand-dug in a commercial field, stored at 4 C for 42 hr, then warmed to 22 C, submerged in a suspension of Ecc, and exposed to hydrostatic pressures of 5 or 350 cm. After 5 min, the tubers were removed from the suspension; five were placed in the mist chamber and five were air-dried for 2 hr, then moistened with water and incubated. The incubation period for these tubers was reduced from 96 to 72 hr because of the high level of disease observed in the nondried control treatment after the shorter time interval. A second group of freshly hand-harvested tubers (cultivar Russet Burbank) was used in a similar test in which water alone or suspensions of Ecc were included as contrasting treatments. These tubers were hand-harvested from plots before the vines were killed and stored overnight at 20 C. Twenty-tuber samples were submerged for 5 min and exposed to hydrostatic pressures of 5 or 180 cm. Ten of the tubers in each sample were placed in the mist chamber and 10 dried in air for 2 hr, moistened, and incubated in the mist chamber.

The effect of incomplete drying on the soft rot potential of inoculated, uncured tubers was examined with a second sample of the hand-harvested Russet Burbank tubers. The tubers had been stored at 4 C for 11 days before being warmed to 22 C, submerged in a suspension of Ecc, and exposed or not to 350 cm of hydrostatic pressure. Inoculated tubers were either placed directly into the mist chamber or fan-dried for about 30 min; at that time, about 50–90% of the tuber surfaces appeared to be dry. These tubers were then remoistened and incubated.

The effects of the following factors on disease severity were examined in a factorially designed test with machine-harvested tubers (Russet Burbank tested about 48 hr after harvest): 1) duration of the fan-drying treatment, 2) pathovar of *E. carotovora*, and 3) infiltration. Samples of tubers were submerged in a suspension of Ecc or Eca and treated or not with hydrostatic pressures of 5 or 350 cm. After 5 min, tubers were removed and divided into groups of five. One group was placed directly in the mist chamber. A second group was dried for 1 hr, then moistened and incubated in the mist chamber. The remaining tubers were dried for 3 hr; five were moistened and incubated as before and five were stored in polyethylene bags in the mist chamber for 69 hr, then moistened and incubated.

Freshly injured, new-crop, cured tubers. The effect of a short-term storage after fresh injury and drying on soft rot potential was examined. Possible interactions of these factors with inoculum level and infiltration were included in the factorially designed test. Commercially stored tubers (Russet Burbank stored about 6 wk) were warmed to 22 C and exposed to water and two inoculum levels (5×10^6 or 5×10^7 cfu of Ecc per milliliter), two hydrostatic pressures (5 or 530 cm for 5 min), with or without fresh injury, and three dry treatments (none, fan-dried for 1 hr or fan-dried for 1 hr followed by storage under intermittent mist for 71 hr). Before inoculation, half of the tubers were uniformly injured at four points with a pendulum-type bruising instrument described previously (2). The 530-cm hydrostatic pressure treatment infiltrated lenticels with Ecc. Lenticels on representative tubers immersed in diluted india ink and treated with 530 cm of pressure were infiltrated within 1 min. After the air-drying treatments, the tubers were moistened with water and incubated as indicated before.

Population changes. Changes in the number of soft rot *Erwinia* in the peel associated with a 2-hr air-drying treatment were examined with the new-crop, stored Russet Burbank tubers. They were submerged in a suspension of Ecc for 5 min with 5 or 530 cm of hydrostatic pressure and dried for 2 hr. Two groups of five tubers from each treatment were peeled with a household-type potato peeler. Wet weight of the peel (about 1 mm thick) was about 0.1 g/cm^2. Peel samples (25 g each) were blended in 100 ml of sterile distilled water for about 1 min. The peel suspension was diluted and the number of soft rot *Erwinia* determined as described previously (3).

RESULTS

Treatments. *Surface-contaminated, cured tubers.* In general, drying treatments suppressed bacterial soft rot in all tests except those in which bacteria had infiltrated tuber lenticels. When tubers from commercial storage were submerged in a suspension of Ecc for 64 min and incubated in the mist chamber, more than 75% of their surfaces were decayed within 4 days. If the tubers were air-dried for 2 hr before incubation, however, the percentage of decayed surface area (disease severity) was 33 or 1%, depending on whether the tubers were moistened or not with tap water before incubation, respectively. Base-level disease severity for this sample of tubers was 0.8%.

Air-drying also decreased disease severity when cured tubers were treated with hydrostatic pressures (180 or 530 cm) while submerged in water or in cell suspensions of Ecc but were not infiltrated with bacteria (Table 1). Severity was higher when tubers were exposed to higher hydrostatic pressures, submerged in cell suspensions of Ecc instead of water, or moistened before incubation. An increase in the air-drying period usually decreased disease severity unless it was already very low. Decreases in disease severity associated with air-drying were similar at each level of hydrostatic pressure; however, moistening tubers before incubation did not increase severity to a similar degree at each level of the air-drying treatments. In two of the four nondried treatments, moistening tubers with tap water before incubation

Table 1. Effects of drying and rewetting on severity of bacterial soft rot (percentage of surface area decayed) in potato tubers after inoculation by submersion at two hydrostatic pressures (cm) in a suspension of *Erwinia carotovora* pv. *carotovora* or water[a]

Drying period (hr)	Suspension of *E. carotovora*[b]	Percentage of surface area decayed after indicated hydrostatic pressure (cm)			
		180		530	
		Dry	Rewetted[c]	Dry	Rewetted
0	−	8[d,e]	7	8	20
	+	21	36	51	49
2	−	1	11	3	4
	+	1	9	4	27
4	−	0	4	0	4
	+	1	5	5	14

[a] Tubers submerged with hydrostatic pressure for 4 min, then dried on rack for 0–4 hr and incubated in mist chamber for 96 hr at 20 C.
[b] + = Suspension containing 5×10^5 cfu per milliliter in tap water; − = tap water alone.
[c] Surfaces sprayed with tap water before incubation.
[d] Each value is the average of 10 tubers.
[e] Probabilities for effects of hydrostatic pressure, inoculum, drying, and rewetting were significant at 0.0001. Probabilities for effects of interactions of drying × rewetting, drying × inoculum, and depth × inoculum were significant at 0.0001.

resulted in increased disease.

Infiltrated, freshly harvested tubers. Marked reductions in disease were also associated with air-drying in tests on freshly harvested potatoes, provided lenticels were not infiltrated with bacteria during inoculation (Table 2). The base levels of disease severity were 9 and 12% for the Superior and Russet Burbank tubers, respectively. Cultivar and infiltration as well as cultivar, infiltration, and air-drying factors interacted, probably because air-drying had little effect on disease in the infiltrated Superior tubers, whereas it reduced disease significantly in the infiltrated Russet Burbank tubers. Failure of air-drying to suppress disease in the infiltrated Superior tubers may be associated with the greater hydrostatic pressure (350 cm) (hence increased infiltration) used on these tubers in contrast with that used on the Russet Burbank tubers (180 cm).

Russet Burbank tubers were also submerged in tap water and infiltrated. Much less disease developed than when these tubers were infiltrated with Ecc, but disease in the water-infiltrated tubers was not suppressed by air-drying. Disease severities were 15 and 13% for the nondried and dried, noninfiltrated and 25 and 26% for the nondried and dried, infiltrated treatments, respectively.

When tubers were dried only until most of the surface appeared dry, disease severity was similar to that in the nondried control tubers. Severities of 32, 36, 49, and 50% were observed in tubers that were not infiltrated, without or with partial drying, and in tubers that were infiltrated, without or with partial drying, respectively.

In contrast, increases in the drying period, including storage in polyethylene bags, suppressed disease after inoculation with either of two pathovars of *E. carotovora* in potatoes harvested by machine (Table 3). Disease was not suppressed, however, when tubers inoculated with Eca were dried for 1 or 3 hr, probably because the disease level after inoculation with Eca was quite similar to the base level for these tubers. When dried tubers were stored in polyethylene bags for 69 hr, severity in each treatment combination was suppressed, but that treatment also reduced the base level of disease severity from 20 to 6%.

In treatments using Ecc, hydrostatic pressures and air-drying treatments interacted ($P = 0.0047$), because disease severity was decreased more by drying when tubers were infiltrated than when surface-contaminated. This contrasted with initial results in which disease in infiltrated tubers was not significantly affected by air-drying.

In tests where disease was suppressed the most by air-drying, the tubers used had a relatively low base level of disease severity. In contrast, when uncured tubers were used, disease suppression was often not as great. Air-drying had little effect on the base-level soft rot potential unless the drying period was increased from about 2 to about 71 hr. Fresh injury is one of the factors during commercial harvest and handling that contributes to high soft rot potentials in freshly harvested tubers (3,9,11). The possible interaction of fresh injuries, high inoculum levels, and infiltration with air-drying on soft rot potential was examined (Table 4). Stored, new-crop tubers were bruised in four locations each to simulate severe injury associated with mechanical

Table 2. Effects of potato cultivar, infiltration of lenticels, and air-drying on severity of bacterial soft rot following incubation of potato tubers inoculated by submersion in a suspension of *Erwinia carotovora* pv. *carotovora*[a]

Cultivar	Infiltration	Percentage of surface area decayed	
		Not dried	Air-dried
Superior	−	79[b,c]	17
	+	90	84
Russet Burbank	−	80	46
	+	94	54

[a] Tubers submerged in 5×10^6 cfu per milliliter of *E. carotovora* pv. *carotovora* and infiltrated for 5 min under high hydrostatic pressure (180 and 350 cm for Russet Burbank and Superior, respectively) or not, removed, air-dried for 2 hr, moistened with tap water, and incubated in a mist chamber at 20 C (72 and 96 hr for Superior and Russet Burbank, respectively).

[b] Values for Superior and Russet Burbank were averages of five and 10 tubers, respectively.

[c] Probabilities for effects of cultivar, infiltration, air-drying, and interactions of cultivar × infiltration and cultivar × infiltration × air-drying were significant at 0.7194, 0.0001, 0.0001, 0.9263, and 0.0263, respectively.

Table 3. Effects of pathovar of *Erwinia carotovora*, infiltration of lenticels, and drying period on severity of bacterial soft rot (percentage of surface area decayed) after incubation of potato tubers inoculated by submersion in a bacterial suspension[a]

Drying period (hr)	Percentage of surface area decayed			
	pv. *carotovora*		pv. *atroseptica*	
	Not infiltrated	Infiltrated	Not infiltrated	Infiltrated
0	44[b,c]	84	19	30
1	31	38	22	31
3	22	29	15	33
72	2	13	4	5

[a] Tubers submerged in 5×10^6 cfu per milliliter of indicated pathovar and exposed to hydrostatic pressure of 5 (not infiltrated) or 350 (infiltrated) cm for 5 min, then incubated in mist chamber (control) for 96 hr at 20 C or dried with a fan for 1 or 3 hr, rewetted, and incubated or dried for 3 hr, placed in polyethylene bags for 69 hr, then rewetted and incubated in mist chamber.

[b] Each value is the average of five tubers.

[c] Probabilities for effects of pathovar, hydrostatic pressure, and drying were significant at 0.0054, 0.0003, and 0.0001, respectively. Probabilities for effects of interactions of pathovar × drying and hydrostatic pressure × drying were significant at 0.0006 and 0.0351, respectively.

Table 4. Effects of immersion depth, injury, inoculum concentration, and drying on severity of bacterial soft rot (percentage of surface area decayed) in potato tubers stored wet for 96 hr after inoculation by immersion in a suspension of *Erwinia carotovora* pv. *carotovora*[a,b]

Drying period (hr)	Inoculum concentration ($\log_{10}$, cfu/ml)	Percentage of surface area decayed			
		Not infiltrated		Infiltrated	
		Nonbruised	Bruised	Nonbruised	Bruised
0	7.7	62[c,d]	56	74	90
	6.7	44	53	76	89
	0.0	48	53	53	75
1	7.7	15	9	51	80
	6.7	22	13	61	58
	0.0	11	17	17	31
96	7.7	23	29	43	53
	6.7	3	15	33	37
	0.0	7	9	30	27

[a] Tubers at room temperature were bruised at four points (two on each side) by a uniform blow from a rounded metal weight (pendulum bruising device) weighing 100 g and traveling a distance of 30 cm.

[b] Tubers submerged in 5×10^6 cfu per milliliter of *E. carotovora* pv. *carotovora* or tap water and exposed to hydrostatic pressures of 5 (not infiltrated) or 530 (infiltrated) cm for 5 min, removed, and placed on metal rack or incubated in mist chamber for 96 hr at 20 C. Tubers on metal rack were dried with a fan for 1 hr, rewetted, and incubated or stored in ≥90% RH at 20 C for 96 hr, then rewetted and incubated.

[c] Each value is the average of five tubers.

[d] Probabilities for effects of inoculum, infiltration, drying, and injury were significant at 0.0001, 0.0001, and 0.0272, respectively. Probabilities for effects of two-way interactions were not significant.

harvest.

Infiltration, high inoculum levels, and bruising enhanced disease development, whereas drying suppressed it. The effect of fresh injury appeared directly related to the severity and type of injury. Soft rot lesions were usually observed at sites where the periderm was visibly cracked. In contrast, when the periderm remained intact, bruised tissues were usually darkened and necrotic but often free of soft rot.

When these tubers were stored for a short period in a humid room, disease severity was reduced to near base levels (4%) for only three of the 12 treatment combinations. Drying was more likely to reduce the soft rot potential of inoculated tubers to preexisting levels in the absence of infiltration, fresh injury, and high populations of Ecc.

Population changes. A short drying period may reduce the number of viable soft rot *Erwinia* in the peel. With new-crop tubers from commercial storage, the populations of soft rot *Erwinia* in the peel after inoculation and rinsing with water were 3.7 and 8×10^5 cfu per gram for surface-contaminated and infiltrated tubers, respectively. However, a 2-hr drying treatment reduced these populations to 1.3 and 2.7×10^5 cfu per gram respectively. Air-drying also reduced the number of bacteria on the tuber surface that could be suspended in water during a gentle rinse with tap water from 1.4×10^5 to 1.7×10^3 cfu per gram and from 1.2×10^5 to 2.4×10^3 cfu per gram for surface-contaminated and infiltrated tubers, respectively.

DISCUSSION

The high soft rot potential associated with immersion in suspensions of Ecc was markedly reduced by thoroughly drying tubers before they were moistened and incubated. This reduction may have been associated with the effect of air-drying in reducing the population of soft rot *Erwinia* on tuber surfaces. A 2-hr air-drying treatment reduced the number of soft rot *Erwinia* (by a factor of 100) that could be rinsed from the surface with water. Soft rot *Erwinia* cells on the surfaces of tubers exposed to the external environment should be killed readily by desiccation (8). On the other hand, a certain percentage of these bacteria may survive for long periods in protected positions, as in lenticels (10,11).

Bacteria that have infiltrated living tuber tissues are also well protected from the external environment. Air-drying for 1–3 hr should not, and in our tests did not, reduce the soft rot potential to near the level that existed before infiltration. Tubers were infiltrated because of high hydrostatic pressures (180–530 cm) applied to the bacterial suspensions in which they were submerged. However, prolonged submersion periods (3.5 hr or more) also may lead to infiltration (1). Therefore, soft rot *Erwinia* may infiltrate tuber lenticels before harvest if fields are flooded.

During harvest, bacteria may also enter injuries, where they are protected from drying. High base-level soft rot potentials (9–20%) were associated with samples of fresh, mechanically harvested tubers. In an earlier report, disease levels were higher in fresh, mechanically harvested tubers than in hand-harvested ones in tests where dry tubers were brought into the laboratory, then moistened and incubated in a mist chamber (9).

On the other hand, death of bacteria on tuber surfaces by desiccation may not be the primary or sole reason for the beneficial effects of air-drying. In a previous report (3), rinsing the surfaces of inoculated tubers for 15 sec with a gentle stream of deionized water also led to a nearly 100-fold reduction in the surface population of soft rot *Erwinia*, although the number of cells isolated from the peel was not reduced significantly. Unlike the air-drying treatment, however, the water rinse did not affect subsequent levels of disease. It is possible that the bacteria in lenticels or wounds, not superficial ones, were responsible for infection during incubation in this experiment. The bound portion of the total population of *Erwinia* on the tuber appeared to be reduced less than threefold if at all by the 2-hr air-drying treatment.

Water loss from outer tuber tissues also may have contributed to the effect of drying on soft rot potential. Previously, an increase in water potential of tuber tissues was associcated with a reduction in soft rot potential (6).

The correlation between the suppression of soft rot by air-drying under experimental conditions and the effect of tuber passage over sponge rollers or sponge rollers plus heated-air driers in a commercial packinghouse is not clear. Partially dried tubers had the same level of disease as those that were not dried. Because tubers sampled after passage through driers in a packinghouse are often still damp to the touch, additional tests are needed on this subject (J. A. Bartz, *unpublished*). If this condition represents the normal situation in packinghouses, thorough drying may not occur until after tubers have been packaged and held in a well-ventilated environment for an extended period. If packaged tubers are well ventilated, the probability that tubers would become thoroughly dried is increased. Under commercial conditions, poorly ventilated polyethylene bags should be avoided. However, when well-dried tubers were enclosed in unvented polyethylene bags, lesions did not develop and the potential for soft rot did not increase.

As noted before, when dried tubers were stored under humid conditions for 69–95 hr before incubation in the mist chamber, the soft rot potential decreased. This reduction may be related to wound healing and suberization (9), although most suberization does not occur until after 4 days at 22 C (7). Short-term, on-site storage of bagged tubers at the packinghouse in a cool, well-aerated environment with air-conditioning equipment operating during warm periods could be an important practice in reducing losses to bacterial soft rot in freshly washed tubers, especially if lenticels have become infiltrated with soft-rot *Erwinia*. As long as free moisture is removed from the surfaces of sound, healthy tubers within about 16 hr after they have been flumed and washed, the threat of bacterial soft rot in tubers kept dry thereafter is minimal (4). The only remaining danger would be decay originating in excessively damaged tubers. Most of these could be culled as the potatoes pass over sorting belts before packaging.

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LITERATURE CITED

1. Adams, M. J. 1975. Potato tuber lenticels: Susceptibility to infection by *Erwinia carotovora* var. *atroseptica* and *Phytophthora infestans*. Ann. Appl. Biol. 79:275-283.
2. Bartz, J. A., and Kelman, A. 1984. Effect of temperature on the inoculation of potato tubers by immersion in suspensions of *Erwinia carotovora*. Am. Potato J. 61:485-493.
3. Bartz, J. A., and Kelman, A. 1984. Inoculation of potato tubers with *Erwinia carotovora* during simulated commercial washing and fluming practices. Am. Potato J. 61:495-507.
4. Bartz, J. A., and Kelman, A. 1985. Infiltration lenticels of potato tubers by *Erwinia carotovora* pv. *carotovora* under hydrostatic pressure in relation to bacterial soft rot. Plant Dis. 69:69-74.
5. Horsfall, J. G., and Barratt, R. W. 1945. An improved grading system for measuring plant diseases. (Abstr.) Phytopathology 35:655.
6. Kelman, A., Baughn, J. W., and Maher, E. A. 1978. The relationship of bacterial soft rot susceptibility to water status of potato tubers. (Abstr.) Phytopathol. News 12:178.
7. Kolattukudy, P. E. 1981. Structure, biosynthesis and biodegradation of cutin and suberin. Annu. Rev. Plant Physiol. 32:539-567.
8. Leben, C. 1974. Survival of plant pathogenic bacteria. Ohio Agric. Res. Dev. Cent. Spec. Circ. 100. 21 pp.
9. Lund, B. M., and Kelman, A. 1977. Determination of the potential for development of bacterial soft rot of potatoes. Am. Potato J. 54:211-225.
10. Perombelon, M. C. M. 1973. Sites of contamination and numbers of *Erwinia carotovora* present in stored seed potato stocks in Scotland. Ann. Appl. Biol. 74:59-65.
11. Perombelon, M. C. M., and Kelman, A. 1980. Ecology of the soft rot *Erwinias*. Annu. Rev. Phytopathol. 18:361-387.
12. Ruehle, G. D. 1940. Bacterial soft rot of potatoes in Southern Florida. Fla. Agric. Exp. Stn. Bull. 348. 36 pp.