BACTERIAL SOFT ROT POTENTIAL: A MEANS OF ASSESSING POTATO TUBER QUALITY

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During the past two decades, various practices and controls have been developed that have greatly reduced losses resulting from bacterial soft rot and blackleg. Nevertheless, severe losses from this disease still occur periodically. In some instances, improvements in procedures for the harvesting, handling, and storing of potatoes may have increased the possibilities of contamination and infection of potato tubers by soft rot bacteria. In particular, increased mechanization in storage, grading, and packaging has enhanced the prospects of mechanical bruising which contributes to the decay problem. Thus, there is a need for techniques that would enable us to examine tuber quality and to assess those steps in potato production and storage that cause mechanical damage and increase bacterial contamination.

The purpose of this paper is to present information on a technique that detects damage in tubers based on severity of bacterial soft rot that occurs when tubers are placed under the stress conditions favorable for decay. At the present time, there are no standardized procedures available to provide a reliable index of the potential for seed piece decay in a given seed lot. Very elaborate procedures have been developed in seed certification programs to determine the level of virus infection and certain other diseases in potato seed. However, there is still the question as to whether a given seed lot will perform as desired when planted under the wide range of conditions that can exist after planting.

At the time of harvest, simple procedures have been developed to assess bruise damage. This involves removing the peel chemically and making a visual assessment of the number and extent of bruised areas that are visible. However, all damage does not necessarily manifest itself by a change in color or a physical break in the tissue. Thus, some phase of tissue injury may be overlooked, and a sensitive assay is needed for this type of damage.

At the present time, no quantitative measures are available to determine when or whether a given lot of potatoes placed in a storage bin has been properly cured. Finally, it is also not possible to determine readily the degree to which specific steps in the handling and grading process contribute to decay problems in transit.

During the past three years, we have been experimenting with a procedure that shows promise as a means of providing needed information on tuber quality and decay potential after each of the steps in potato production and handling listed above. The procedure involves placing potato tubers in a mist chamber and maintaining the tubers for a period of 96 hours at a temperature of 20° C (68° F) (Lund and Kelman, 1977). In the mist chamber, the potato periderm is covered continuously with a thin film of water. Within a few hours it becomes anaerobic (Burton and Wigginton, 1970; Wigginton, 1973) and its defense mechanisms against infection by soft rot bacteria are markedly lowered. The soft rot bacteria (Erwinia spp.) have the capacity of growing under conditions where oxygen is limited; thus, they can develop rapidly in lenticels and particularly in those areas where the tissue has been broken (DeBoer and Kelman, 1975; Perombelon and Lowe, 1975). The mist chamber method provides a means for evaluating the soft rot potential of a relatively large number of tubers in a four-day period. Currently, we use large metal racks with four shelves; plastic film underneath each shelf drains off the excess water and prevents dripping on tubers placed on lower shelves. With the assistance of Dr. F. Buelow of our Department of Agricultural Engineering, a potato bruiser has been constructed which makes it possible to injure tubers uniformly. With this pendulum-type bruising device, the type of bruise can be produced that might occur in the normal handling of the potato.

If soft rot bacteria are present, the potato will usually decay at the points of impact. By removing the decayed area from bruised potatoes after the incubation in the mist chamber, it is possible to measure the percent of tuber tissue affected. For instance, it is possible to determine the influence of temperature on severity of bruising and decay by using these procedures (Table 1). Tubers were placed at three different temperatures for a period of 48 hours; then each tuber was bruised at two points with the pendulum bruiser. One group of tubers was placed in the mist chamber and a second lot was placed at room temperature (25^{o} C) and observed after 48 hours for the presence of shatter bruise and black spot. At 4^{o} C, the greatest injury and the most severe soft rot occurred. The percentage of bruised areas that decayed declined from 85% at 4^{o} C to 50% at 24^{o} C. However, there was a much greater decline in visible damage as the temperature increased so that at 24^{o} C the percentage of bruised areas that showed visible damage was 25%. This indicated that the soft rot bacteria may be able to detect bruises which cannot be seen by the naked eye and, thus, provide us with a means of assaying potatoes for damage which cannot be determined by the procedures currently available.

This spring, tuber samples were obtained from the storage bins of three different seed growers (Table 2). These seed samples were taken from the bins shortly before the seed potatoes were shipped to commercial growers in central Wisconsin. At the time the seed lots arrived and were placed in temporary storage prior to planting, a second set of samples was taken from each of these seed lots. These were all assayed by the mist chamber procedure. The percentage of seed tubers that decayed increased markedly after they had been subjected to the normal grading, shipping, and bin loading procedures. It is important to note that initially the seed had very low soft rot readings. The other interesting aspect of this particular test was the fact that these seed lots had the same ranking in the initial decay readings, and in the readings taken after shipment.

At the time of harvest, the mist chamber procedure can also be used to detect damage during the harvesting and storing process (Table 3). This is illustrated by results with samples taken after the tubers have passed from the digger onto a truck and then are washed and graded and placed in the plastic bags for shipment. Over 80% of the tubers taken at the end of this process had decayed after mist chamber exposure; less than 10% of the hand-dug potatoes were decayed. As one phase of the assay procedure, the periderm or potato peel can be removed, chopped in a Waring blendor, and plated on a medium which is selective for the soft rot bacteria that are involved in tuber decay (Cuppels and Kelman, 1974). Using this procedure on the same samples listed in Table 3, the numbers of soft rot bacteria per gm of peel increased markedly as the tubers were moved from the field through the packing shed. At the time the tubers are placed in the bag, the numbers of bacteria have increased from less than 100,000 to over 10 million per gram of peel. In a similar study (Table 4), the major increase in severity of soft rot occurred as the potatoes were moved from the truck and into the storage area via the bin piler. Apparently, a high proportion of the damage occurred after the harvesting operation. Furthermore, during the harvesting operation, the numbers of bacteria per gram of tuber peel increase from approximately 100 to 1 million (Table 4).

The mist chamber method can also be used very effectively to monitor the curing process. It is important to recognize that most potatoes placed in a storage bin are usually thoroughly bruised and contaminated. If they were placed under the optimal conditions for bacterial soft rot to develop, it is likely that few would survive. However, during the curing process, the ability of the potato to recover is conditioned to some extent on the amount of damage that occurred during the harvesting and bin piling procedure. In one series of experiments, tubers from one field were sampled from various points in the harvesting operation; samples were placed in the storage bin where the potatoes from that field were placed. Samples were examined by the mist chamber procedure at the time of harvest and again after eight weeks when the curing had been completed. Those potatoes taken from the digger boom showed a remarkable recovery (Table 5). Initially, over 55% of the tubers had decayed, but after the curing procedure only 1% of the tubers in that particular lot decayed. However, a sample from the bin piler boom still showed a relatively high percentage of decayed tubers (55%), indicating that the recovery of these potatoes had not been equal to that of the tubers from the digger boom. Two conclusions can be drawn from this particular experiment; 1) it is possible to monitor the recovery of tubers in the curing process using the mist chamber procedure, and 2) tubers with relatively high soft rot potentials at the time they enter the storage bin can, under proper conditions, recover to the point where none of them will decay even when placed under the high stress conditions of the mist chamber technique. Tubers which are badly bruised and damaged may not fully recover and, thus, provide a potential hazard if conditions in the storage are not maintained at a highly favorable level. It is necessary to emphasize that high soft rot readings to not indicate necessarily that a problem will develop in storage, but merely that the potential for decay exists.

A potential for damage also occurs during grading and packing procedures. This is illustrated in a test in which tubers were taken from a large storage bin prior to the time that they were moved via a long flume to the packing area. A second set of samples was taken at the end of the grading line as the tubers were placed in plastic bags for shipping (Table 6). The severity of soft rot increased greatly as the potatoes passed through the packing procedure; thus, the unwashed tubers from the bin had a soft rot percentage of 6%, whereas 91% of the washed potatoes had soft rot lesions. In this same test, the number of bacteria increased from 63 per gram of peel in the bin to almost 2 million per gram of peel after fluming and washing. Although tubers with high soft rot potentials can reach the shipping point safely, if a film of water develops and they are not kept cool in transit, severe soft rot problems can occur.

In summary, it appears that the mist chamber incubation procedure has the potential for application in the following ways:

1) It may provide a means of evaluating seed quality and the potential for seed piece decay. In our initial studies, a high soft rot potential index in the seed has, in general, indicated that a particular seed lot would have also a high potential for seed piece decay or the development of blackleg. This was greatly influenced by environmental conditions after planting.

2) The second major potential application is in the evaluation of the curing procedure. It is very difficult at the present time to determine the specific pattern of temperature, relative humidity, and air movement that provides the optimal conditions for curing or to determine whether a given lot of potatoes can be held for an extended storage period. As has been demonstrated, soft rot potential drops rapidly as the curing process continues; this decline can be used as a means of monitoring the effectiveness of the curing and holding procedure.

3) The method can be used to detect those steps in the harvesting procedure that may be contributing to bruise damage. It appears that the bacteria can detect very slight damage to tuber tissue which is not visible to the human eye.

4) The steps in packing procedures that increase soft rot potential can also be monitored in a packing shed as well as in the grading and movement of seed potatoes to the commercial grower.

It is important, however, to recognize that there are various facets of this procedure which need additional study. One of the disadvantages of the method is the fact that it takes at least four days to obtain a reading of soft rot potential. In order to make a proper assessment, the sampling procedure is extremely important. At least 30-40 tubers are needed per sample and preferably three-four samples should be used for any valid assessment to be made. Of course, there are many problems associated with trying to sample bins which may contain 25,000-100,000 hundredweight. Furthermore, the sampling procedure we have used involves taking at least four samples from a bin area at a depth of approximately one foot in the bin. This does not provide a true picture of the status of tubers at various levels in an 18-foot pile. It is essential also to standardize the methods for sampling and transporting samples for testing because carelessness in the sampling procedure or handling the tubers may cause erroneous results. Finally, it is essential to have complete information on field practices and environmental conditions in order to interpret the data. Although additional testing and evaluation are required, the results obtained thus far with the mist chamber procedure are encouraging and indicate that this technique can be developed as a reliable simple method for the assessment of damage to tubers and the potential for bacterial soft rot in the various phases of potato production.

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Table 1. Bacterial soft rot [a/] and mechanical damage [b/] in relation to temperature.

Tuber temperature at time of bruising	Ave. wt. of decayed tissue (gm)	Injured area decayed (%)	Shatter bruises (%)	Visible damage (%)
4°C	1.4	85	50	83
16°C	1.0	76	15	48
24°C	0.4	50	8	25

a/ Tubers were incubated in a mist chamber for 96 hr at 20°C after bruising.

b/ Tubers were bruised at four points using a pendulum type of bruising device (100 gm wt).

Table 2. Bacterial soft rot in seed potatoes sampled from bins of certified growers prior to grading and shipment and after arrival and placement in temporary storage prior to planting.

Seed grower lot	% tubers with soft rot[a/]	
	From seed bins[b/]	After shipment[c/]
A	3	48
B	17[c/]	89
C	5	78

[a/] Tubers were incubated in a mist chamber for 96 hr at 20°C.

[b/] Based on two 30-tuber samples.

[c/] Based on four 30-tuber samples.

Table 3. Percent of tubers with bacterial soft rot and numbers of soft rot bacteria on potato tubers sampled at different steps in harvesting and packing.

Sample point	Percent tubers with bacterial soft rot[a/]	Number of soft rot bacteria/gm of peel[b/]
Hand-dug	8	55,000
Truck	16	380,000
Packing for shipment	83	10,000,000

[a/] Based on 30-tuber samples incubated for 96 hr at 20°C in a mist chamber.

[b/] Based on peel sample from 10 tubers; dilution platings on a crystal violet pectate medium (Cuppels and Kelman, 1974).

Table 4. Percent of tubers with bacterial soft rot and numbers of soft rot bacteria on potatoes taken at different points in harvesting and storing procedures.

Sample point	Percent tubers with bacterial soft rot[a]	Number of soft rot bacteria/gm of peel[b]
Hand-dug	20	100
Digger	30	1,500
Bin piler	100	700,000

a/ Based on 30-tuber samples incubated for 96 hr at 20°C in a mist chamber.

b/ Based on peel sample from 10 tubers; dilution platings on a crystal violet pectate medium (Cuppels and Kelman, 1974).

Table 5. Percent soft rot in potatoes from the digger boom and the bin piler at harvest and after curing.

Sampling point	Percent tubers with bacterial soft rot at harvest[a]	Percent tubers with bacterial soft rot after curing[b]
Digger boom	55	1.0
Bin piler	100	55

a/ Tubers incubated in the mist chamber for 96 hr at 20°C.

b/ Digger boom tuber samples in open mesh bags were placed in area of storage bin from which bin piler samples were taken after 2 months of storage.

Table 6. Fluming of stored potatoes in relation to bacterial soft rot development.

Sample source	Percent tubers with soft rot	Number of soft rot bacteria/gm peel
From storage bin	6	63
After fluming and washing	91	1,700,000