EFFICACY OF CHLORINE DIOXIDE IN POTATO STORAGE ENVIRONMENTS

Gale E. Kleinkopf, Nora L. Olsen, and Lynn K. Woodell

Chlorine dioxide gas prepared from a buffered solution of sodium chlorite by activation with a food grade acid has been shown to effectively control many potato pathogens in laboratory experiments. Fusarium dry rot, bacterial soft rot, silver scurf, and late blight organisms can be controlled, even killed, under appropriate laboratory conditions. The active ingredient, chlorine dioxide gas dissolved in an aqueous solution, is an effective biocide when it is in contact with various disease organisms. Does this same efficacy exist when the product is applied to potatoes in or going into storage?

Several states have adopted Section 18 emergency use provisions for chlorine dioxide to help control problems associated with late blight in storage. According to the allowable use under the Section 18 label, several concentrations of activated chlorine dioxide may be applied to potatoes going into storage or to potatoes at risk in storage. Consequently, chlorine dioxide has been applied as a control agent to help limit problems associated with tuber blight. **However, chlorine dioxide is not a substitute for a good storage management program.** An important question is: "Does chlorine dioxide work as well in storage as projected from laboratory experiments?"

First of all, chlorine dioxide products must be activated by the application of a food grade acid before it is useful. Experiments at the University of Idaho Kimberly Storage Facility and at North Dakota State University have definitely shown benefit from activation (Figure1, Table 1). Approximately 90 to 900 times as much non-activated material is required to reduce disease organisms in laboratory experimentation as the activated product. Consequently, the labels require that the material must be activated before application to potatoes. Even though some pathogen reduction may occur with the non-activated product, disease reduction or control is not at an acceptable level.

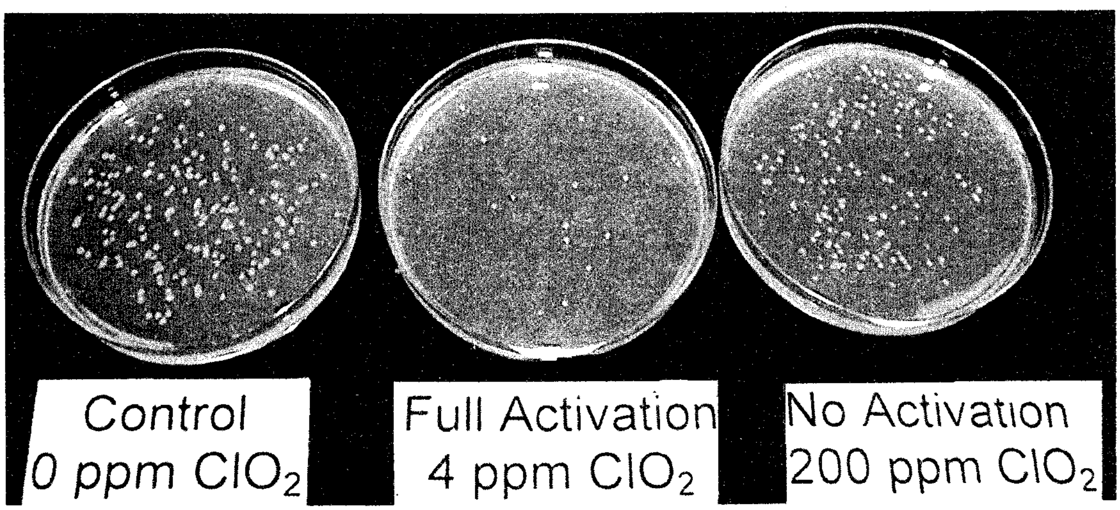

Figure 1. Soft rot viability using different ClO_2 activation levels.

Presented at Idaho Potato Conference on January 17, 2001.

The activation step, adding a food grade acid to the buffered solutions, is important for generating the active ingredient, chlorine dioxide gas. This gas is dissolved in the aqueous dilution that is applied to potatoes. Best activation requires the pH of the acid/solution mixture to be reduced to 2.6. After a short period of time, between 30 and 50 percent of the active ingredient (chlorine dioxide gas) is produced in the mixture that is then diluted to a working solution for application to potatoes. Because chlorine dioxide is a gas dissolved in a water solution (soluble in aqueous solutions up to about 4000 ppm), it can easily diffuse out of the solution during the application procedure (Table 2). We found that the gas escapes in alarming quantities when the solution is sprayed on the potatoes using high-pressure spray bars. More of the gas is retained in the solution when we used coarse nozzles and low pressure (Table 3). However, the coverage of the spray on the potatoes is generally lower as the droplet size is increased, given the allowable application rate at 0.5 gallons per ton of potatoes. If we double the amount of solution applied to the potatoes, i.e., 1 gallon per ton, we start to see some reduction in viability of silver scurf spores (Table 4). Even at 5 times the allowable application rate only a little more than half of the silver scurf spores on the potato tubers are killed. At 0.5 gallons per ton application rate the chlorine dioxide gas in solution very likely dissipates before it has a chance to limit the viability of fungal spores.

The University of Idaho **does not recommend** application rates of more than 0.5 gallons per ton going into storage due to the increased risk of disease development on wet potatoes. **Remember, none of these disinfectant materials will**

Table 1. ClO_2 concentrations that reduce pathogen populations by 50% using different activation levels

Treatment	Dry Rot	Soft Rot
	Parts per million	
Nonactivated	965	90
Full Activation	1	1

Table 2. ClO_2 after using an air assisted sprayer

*Label Dilution ppm	Initial[a] ppm	Remaining ppm	Loss %
200 "Method 1"	2^A	1^A	52^A
400 "Method 1"	3^A	1^A	58^B
2000 "Method 1"	14^B	5^A	65^C
200 "Method 2"	64^C	16^B	75^D
400 "Method 2"	130^D	31^C	76^D
2000 "Method 2"	702^E	167^D	76^D

* "Method 1"-activated with 6 oz., waited 10 minutes, diluted to working solution (per 1999-2000/ Section 18).
"Method 2"-diluted to 2000ppm, activated to pH 2.6, stored in capped bottle 24 hours, diluted to working solution.

[a] Column values followed by the same letters are not significantly different.

Table 3. Loss of ClO_2 by nozzle type and concentration

Treatment ppm	Nozzle type: Fine	Nozzle type: Extremely Coarse
	% Loss	
200	44	25
400	61	44
2000	75	67

Table 4. Percent reduction of silver scurf spores on tubers at two volumes.

Volume gal/ton	Rate[a] 400 ppm	2000 ppm
0.5	0^A	21^A
1.0	3^A	55^B

[a] Column values followed by the same letters are not significantly different

eliminate established disease infection sites in potatoes. The increased risk to wetting potatoes in storage is true for any product applied in higher volumes, whether the product is a thiabendazole, chlorine dioxide and particularly one of the several hydrogen peroxide/acetic acid based materials.

Chlorine dioxide gas that escapes into the atmosphere surrounding the potatoes during application is not available to reduce disease inoculum on the potatoes. And, if the concentrations of gas remaining in the spray solution are too low, no efficacy would be expected. The active ingredient is also lost from solution on application to potatoes as it reacts with the organic load on the potato. More than twice as much of the active ingredient is lost on contact with the potato surfaces (potato skin, dirt, other organic matter) than by diffusion from the liquid solution alone. Even though the material is applied as per Section 18 label, the active ingredient can escape during application and as it reacts with the potato, consequently, producing inconsistent results including negative control of potato pathogens in storage.

Another part of the Section 18 label allows the material to be supplied in the humidification water at 50 to 200 parts per million. When chlorine dioxide is applied through humidification sources (foggers and ultrasonic humidifiers, Table 5) much of the active ingredient is lost as a gas from solution into the surrounding storage atmosphere. In a simulated storage experiments with late blight, only one treatment in two experiments had any effect in reducing the level of tuber blight over the control (Table 6). Even that treatment (about 30 percent reduction in surface infection) had unacceptable levels of tuber blight remaining after chlorine dioxide treatment with maximum label application rates.

Table 5. ClO_2 decay rate with two humidification applicators

	Loss/minute[a]	
Treatment	50 ppm	200 ppm
Ultrasonic humidifier	0.02[A]	0.05[A]
Spinner	0.02[A]	0.05[A]
Control	0.008[B]	0.01[B]

[a]Column values followed by the same letters are not significantly different

These experiments have raised an interesting question. Is the active ingredient, chlorine dioxide gas, an effective biocide as it moves through the pile? This issue is a complex one and difficult to answer. At the Kimberly Storage Research Facility, preliminary results indicate that the gas is scrubbed out of the air rapidly by the potato pile. That is, it reacts with the potatoes to limit its effectiveness for disease control. Are application methods available that will permit chlorine dioxide to be an effective pathogen-control agent for potatoes in storage? Should the application labels for the products be changed to reflect the limited efficacy in storage? Can chlorine dioxide gas be generated at sufficient concentrations to be efficacious in the circulation

Table 6. ClO_2 efficacy on late blight in storage

		Test 1	Test 2
	Treatment (ppm)	% Coverage by late blight lesions	
A	Control, no chlorine dioxide	52	47
A	200 initial	58	51
A	400 spray prior	53	57
A	400 spray prior, 200 initial	56	56
A	400 prior, 200 initial, 50 continuous	34	47
A	50 continuous		53
B	1000 spray prior		42
	LSD (0.05)	8	9

A - all treatments allowed by section 18
B - this treatment is 2.5 times allowable application rates

air of the storage? Additional research is being conducted at both the University of Idaho and North Dakota State University to help answer these questions.

We now know that chlorine dioxide is lost from the activated solution through diffusion from an open container, diffusion out of small droplets from a spray bar and by action on the potatoes themselves. Under controlled conditions in a laboratory, activated chlorine dioxide has good biocidal effects on potato pathogens. It is the transition from the laboratory to the potato storage that has become the real challenge to generating the expected product efficacy. However, many of these disinfectant products have shown good efficacy in other industries. Potato growers are still in need of a reliable disinfectant that can be applied to potatoes to reduce the risk of disease developing in storage. At this time there are no registered products that meet all of these criteria for the potato industry.