Basics of Potato Storage Management

SLIDE 1
This is Steve Johnson, University of Maine Cooperative Extension bringing you this information on potato storage management. It is possible to receive a Maine board of pesticides control recertification credit for this presentation. As this presentation is approximately a half-hour, another presentation would also have to be viewed to receive credit. Additionally, a test must be passed with a minimum of 80% correct answers on each presentation while there is no charge for viewing this information, there is charge for taking each test, whether the tests are passed or not

SLIDE 2
I'm going to be talking about potato storage and how to handle the crop going in as well as classifying diseases into wet or dry rots. It is clear by looking at a rotted potato which it is. The number one rule is a potato storage is not a hospital. Potatoes are not going to get better. If potatoes go in sick, chances are they're going to come out sicker. The best-case scenario is potatoes will come out the way they entered. So understanding that, the best place to do disease management is in the field, before the potatoes enter the storage. Most potato diseases that affect the crop in storage happen in the field and are brought into storage. This can occur anywhere the potatoes are grown or handled, be it when they are harvested, are being loaded into storage, or in the storage building itself. Realistically the time to prevent storage diseases is before they enter the storage.

SLIDE 3
It has been a number of years in Maine since we've seen storages like this, but this one did have potatoes in it. By the way, the potatoes didn't make it. Processors, seed buyers, tablestock customers don't want potatoes that are not from a ventilated, computer-controlled storage. It has been this way for over two decades. With that, many of the quality and the breakdown issues that were very common from storages like this have become nearly a nonissue as we moved into our more modern storage buildings. But we're also putting potatoes into these buildings much faster than a generation ago. Tiny buildings like this are becoming a thing or the past. Buildings like this had potatoes entering in a day what enters in an hour these days. The heat buildup in the pile can be a real issue when today's storage loading rates are used with yesterday's storage building. We bring in a lot more field heat and move potatoes faster than before. We bang the potatoes around a little bit more. The point is that it is the same storage and handling from yesteryear

will not work today. The filling rate is continuing go faster and I dare say it will continue to do so.

SLIDE 4
Getting healthy potatoes into a storage and keeping them that way is the primary objective of the potato-storage manager. They need to provide an environment that will maintain quality through the storage season, whether the storage season is 1 month or 12 months. Again, there's a different approach if potatoes are going to be harvested in September and delivered in August, as opposed to harvesting in September and delivering in December. Potatoes are a living plant. They give off carbon dioxide, take in oxygen, and release heat and moisture, which can cause a potato pile and building to overheat.

Potato piles can start to rot with excess moisture. Potato diseases in storage can increase the moisture and temperature in the building. I've measured as high as 135 degrees Fahrenheit in a potato storage. Biology was happening, giving off heat and moisture.

So the idea is to ventilate to remove excess heat and moisture from the potatoes and the air around the potatoes. This is done through ventilation. And I don't mean opening the doors. I mean turning on the fans to move air. When I started, the new storage had 10 feet between the culverts. This quickly went down to eight feet, and some places are down to six feet now. We know square buildings are going to hold the potatoes more evenly than Quonset buildings, just because of the difference in headspace. Both do a good job with proper management.

SLIDE 5
And so a lot of things have changed, but the ventilation is still key. The goal is to control the temperature and the humidity of the potato storage. Carbon dioxide buildup is an issue that ventilation addresses. If the carbon dioxide is not removed from a processing potato storage, a darkening of the fry color can occur. Virtually every storage that I go into has the carbon dioxide monitored, with the goal to keep it below specific levels. Seed growers have recognized the value in avoiding carbon dioxide buildup as well. Flushing the carbon dioxide out of the storage reduces aging of seed so the seed comes out less stressed. This is a concept that is rapidly gaining converts in other countries as well.

Wet potatoes can be dried out with the ventilation system. Humidity can be added through the ventilation system as well. Generally, there is a greater need for

humidity early in the storage season. The stopcock on the water line on spinning humidifiers can be adjusted, generally closed down from wide open. One hundred percent humidity and wet floors is different than one hundred percent humidity and dry floors. The key is to get the water vapor into the air without having the floor too wet. With a wet floor, there is a risk of moisture condensing onto the potatoes. Condensed moisture on potatoes in storage is where bacteria and fungi develop. Ventilation systems can be used to add moisture or remove moisture from the system.

The ventilation system is managed to minimize the weight loss from to shrink. Not enough moisture or too much air movement right after harvest is going to cause excess shrink in the potatoes. This can lead to problems later in the storage season such as pressure bruises. *Fusarium* can invade the tubers early in the storage season where inadequate moisture delayed or inhibited wound healing, or can invade later into the pressure bruise that commonly results from these situations. This results in potatoes that just aren't that attractive to the end buyer.

The humidification system needs to be able to deliver a gallon of water per about a thousand cubic feet per minute of airflow. Some of the Humidicell coolers, sometimes called swamp coolers, don't have the humidity capacity when the storage temperature is being pulled down. An additional spinning humidifier might be needed during this period, but not later on in the season. Ventilation equipment and monitoring is constantly improving and getting better.

SLIDE 6
Generally a static pressure of a inch and a quarter water column and air velocity of about a thousand feet per minute is required for maintenance of the pile. The large fan capacity is needed to bring the temperature down in the pile.

SLIDE 7
Different end uses require different amounts of airflow. I have some numbers on the screen of seed at 0.8 cubic feet per minute per hundredweight, French fries at 1 cubic feet per minute per hundredweight, and chips at 1.5 cubic feet per minute per hundredweight. I don't think there's any problem going higher than that. And I think it would be a good idea to design it for more than this listed air flow, simply because the air flow can always be backed off but it can be difficult to add more air capacity.

SLIDE 8

When the crop is brought into the storage, use about a 5 degree Fahrenheit lower set point than pulp temperature with a continuous airflow. If the pulp temperature is 60, set the temperature sensors at 58 to be able to pull that cooler air in. Bear in mind the tubers are already at the temperature you want for healing, but do need carbon dioxide removed and oxygen from fresh air brought in. Pulling too cold of air too quickly may cause condensation on the tubers and this can lead to problems in the short term or long term. The continuous air supply is maybe the doors open or the louvers wide open, depending on the situation. I feel the doors shut and the louvers open gives better control of the air coming in for curing. Curing occurs for about two weeks and can start when the storage is being loaded, depending on how long it takes to load the storage.

SLIDE 9

Optimal curing conditions are 50 to 55 degrees Fahrenheit with high humidity—95-100% is optimal, for two weeks. But fresh air is being entered regularly to continuously all this time. The goal is to remove carbon dioxide and provide needed oxygen to heal and cure wounds on the potatoes. This period is like a race, the idea is to give the potato an opportunity to heal itself before *Fusarium* or some other pathogen invades the wound. Given optimal conditions, the potato tuber does an amazing job of this. There have been years that have been extremely dry that it was difficult to impossible to supply enough humidity and temperature conditions for optimal healing and curing conditions. Healing and curing will occur at temperature and humidity outside of optimal, but it will take more time. This is where pathogens get an advantage.

In those difficult dry years, *Fusarium* became a problem as it was not possible to get enough moisture into the air because the air was so dry. Even the point of soaking the concrete floors and adding humidity, the potatoes came in so dry and had been so dry that it was not possible to get the desired moisture into the air for curing.

SLIDE 10

The goal is to cool the pile down 3 to 4 degrees Fahrenheit per week for seed, 1 to 2 degrees Fahrenheit per week for processing, and 2 to 3 degree Fahrenheit per week for tablestock. Too quick a pulldown can shock the potatoes and generally leads to condensate on the potatoes, which is never a good thing. Do the math for your target temperature, it could a couple months to cool them down.

SLIDE 11

Sometimes the potatoes are not ideal and sometimes the conditions are not ideal. And that's really where the art and skill of potato storage management comes in. In many years, the growing may be the easy part. The hard part can be storing the potatoes, and the really hard part is storing them when the conditions aren't perfect or the potatoes are not perfect. Adequate soil moisture for cushioning is critical for bruise reduction and disease reduction. Soil lumps can cause bruises as can not carrying soil all the way up across the primary belt, possibly onto the secondary. So, with good potatoes and a minimal amount of damage occurring during harvest and adequate cooling air available, things are going well.

SLIDE 12
Ideal environmental conditions include cooling air available, no excessive heat during harvest or in the tubers, and no excessive cold. We generally have these conditions, but when we don't, we can run into problems. In some years, those with refrigeration units turned them on for cool down.

SLIDE 13
Storage problem can arise if the crop conditions, harvest conditions, or handling conditions aren't right. This is often manifested in the initial storage conditions, which are really are the first 30 days. This includes the initial cool down and curing period. After that, if the external environmental conditions aren't right, storage problems can occur. Understanding what conditions cause issues helps head off future storage concerns by adjusting the management.

SLIDE 14
For cool and wet harvest conditions, water will be an issue. Run the fans continuously without humidity. With wet and cool harvest conditions, there’s plenty of moisture in the mud harvested with the potatoes as well as in the air, and the potatoes being harvested are right around the curing temperature. If the weather is going to stay wet for a number of days, it may be advantageous to shut the building up and limit the amount of fresh air to what is needed for curing. This may increase the pile temperature slightly, but it will dry the potatoes off.

SLIDE 15
A cold and wet harvest happens more than anyone wants. Snow during harvest or hard freezes that may go down a couple inches into the soil will invariably lead to low-temperature injury. Certainly, in the photograph, one would expect some low temperature injury on those tubers. In processing potatoes, there will be darkening of the processed product, as well as frozen or chilled potatoes coming in along with

frozen soil clods, these soil clods can be sharp and damage potatoes. High tuber damage routinely occurs with these conditions.

Again in this situation, initially run the fans continually. The cold and or frozen potatoes will give off moisture for curing. It is imperative that close attention is paid to the storage as curing is going be extremely important with cold-damaged potatoes. The potatoes are going to need to be warmed up for optimal curing conditions.

SLIDE 16
For a cold and dry harvest, run the fans and the humidifier intermittently as the tuber temperature is near the curing temperature already.

SLIDE 17
For a warm and dry harvest, run the fans and the humidifier continuously during the filling and for the first few days. Modulate the air temperature so there is a 5-degree, or less, difference between the pile and the air temperature for reduction of condensation. The aim is a gradual cool down.

SLIDE 18
If there is an abundance of soft rot in the potatoes coming in, the potatoes still need to be cured, but at a temperature of 50F or lower.

We will use hotspot fans; fans with tarps over a trouble area in the bin. Maybe a load was rained on and the grower thought they might get away with it as they have in the past. These areas are fairly easy to target either by looking at the pile, or with an infrared temperature gun. Hotspot fans, which are about a one-third horsepower fan generally on an inner tube or such, on a tarp with a hole cut in it to pull heat out of the area. And it can do a pretty good job, but it's going to be on there for a good three weeks or more.

SLIDE 19
If potatoes are coming in with a high percentage of soft rot or a high percentage of soft rot is present at the early stages of storage, no humidity should be introduced with potatoes in these conditions. There is plenty of moisture present with rotting potatoes. If the bin is salvaged, expect *Fusarium* to be an issue later on.

We don't have, and we've tried, any information to support application of bactericides through the ventilation system. Therefore, I don't recommend it.

SLIDE 20
If soft rot is present after curing, it's time to really pull the bottom out of the temperature. Lots of air. This often includes hotspot fans. It may also include booster fans in the plenums under the areas where there is a problem.

However, with a high percentage after curing, it's time to move the potatoes any way possible. Generally, they don't last 60 days. Unloading a bin with a Payloader is much faster than loading in with a bin piler.

SLIDE 21
Pink rot is caused by *Phytophthora erythroseptica*. This is becoming an increasing problem over the past few years.

SLIDE 22
Often, there are fields with pink rot in them and they are a potential problem going into storage. I feel our modern storages can handle a 5% late blight, but only about 1% pink rot, and even that may be tough under some conditions. A pink rot is a problem that can spread rapidly, especially with warm potatoes. When tubers are moved around, the pathogen will spread tuber to tuber.

The best thing to do with pink rot in the field is to delay harvest and let the afflicted potatoes rot in the field. This reduces the amount of pink rot coming into storage.

When potatoes come into storage with pink rot, cool the potatoes cooler than you want them, but not cold. And, if the infection level is high, it becomes a salvage operation. Rapid cooling may be warranted where the temperature is brought down quite quickly. However, if these are going into the market, they should be warmed up for at least a day to a day and a half, maybe two days before shipping or bagging. This will allow any breakdown to occur and culling out tubers is easier. Pulling rotting potatoes out before they are put into a bag is far preferable to having them rot in the bag during transport.

Again, this is a wet rot. Cool potatoes to 50 degrees means the cooling air has to be cooler than 50 degrees.

There are some phosphorous acid approaches to pink rot in storage. I worked with and developed a program and a specific applicator. This has pretty much eliminated storage breakdowns in Maine.

SLIDE 23
Late blight is caused by *Phytophthora infestans*. This is a dry rot, but can lead to soft rot. The storage management practices for Late blight are the same as for soft rot.

SLIDE 24
Pythium Leak is caused by *Pythium ultimum*.

Generally, *Pythium* is a problem when harvesting too warm. If harvesting occurs at air temperatures over 75 to 80 Fahrenheit, expect to get *Pythium*. It is time to shut down the harvesting operations at these temperatures as the potatoes come in too warm. This can develop in storage but is a handling issue for our area. The storage management practices for Leak are the same as for soft rot.

The phosphorous acid approaches effective for late blight and pink rot are ineffective for leak in storage.

SLIDE 25
I mentioned some phosphorous acid approaches to pink rot and late blight in storage. The structure is shown on screen. H_3PO_3 is not a fertilizer.

SLIDE 26
Phosphorous acid is not a fertilizer, it is a pesticide. It is a plant resistance inducer, if you will. And it is regulated as a pesticide.

SLIDE 27
Phosphorous acid and phosphoric acid are not the same. Phosphorous dissociates and releases phosphonate which is also called phosphite. This inhibits some pathogens. Phosphoric acid dissociates and releases phosphate. This is a fertilizer, an important distinction

SLIDE 28
I tested these materials Agchlor 310 is a bleach-type material, Rampart, Phostrol, and ProPhyt are all phosphorous acid materials. The rates are full-label rates with a 2x rate of ProPhyt.

SLIDE 29
I also dealt timings of the treatments – how soon after inoculation in my case, or how soon after tuber-to-tuber transfer during loading.

SLIDE 30
I also looked at different rates of material: full rate, half rate, and quarter rate. I inoculated with heavy dose of the late blight pathogen, *Phytophthora infestans*. Again I inoculated to potatoes; waited one hour and treated them with phosphorous acid or other test material, or waited three hours and treated them with phosphorus acid or other test material. I belt sanded tons of potatoes and made a huge mess and actually went through a number of sanding belts as they were designed to sand wood and not potatoes, but it provided an effective infection court. The check, as you can see, was one hundred percent infected all the way across. This is good, it shows the inoculation works. The materials tested at 3.2 ounces or 6.4 ounces per hundredweight showed erosion of control. There really no disease showing up at 12.8 ounces per ton, which is the labeled rate of the material. Using the full-labelled rate is important.

SLIDE 31
This is a study I performed showing how late blight is affected by the timing of the treatment versus the rate of the treatment shown previously. As can be seen here, the check was pretty well annihilated across the board and that Agchlor 310 really didn't do much. This material, like bleach, is inactivated with dirty water or by soil. So, it's not unexpected that this material with dirty potatoes would not control this pathogen in these conditions. Again, I treated potatoes one hour or three hours after inoculation. The paired columns are separate year's data. The phosphorous acid materials used worked like magic. There was no disease, despite heavy inoculation.

SLIDE 32
This is the same situation as the previous tests. How is pink rot, caused by *Phytophthora erythroseptica*, is affected by the timing of treatments. Oxidate was not effective at all, any more than Agchlor310 or the check was for pink rot, but the phosphorous acid material, even a doubling up the rate was absolutely flawless. There was absolutely no pink rot in these two years of study. This has really changed how potatoes are treated entering storage.

SLIDE 33
The labeled rate of carrier is 64 ounces solution per ton. In addition, a critical aspect with phosphorous acid applications is coverage, coverage, coverage.

SLIDE 34
I investigated rate of material previously, so this study is looking at the volume of application. A question that arises is what's more important the coverage or the

carrier. Here I put 12.8 ounces of phosphorous acid, which is the labelled rate, into different rates of water carrier for a total volume of: 64, 32 or 16, and this is again at a full 12.8 ounces. So obviously the 16 ounces is almost pure phosphorous acid. And I ended up getting late blight develop on the quarter rate when I waited one hour and did the treatment. The importance of volume of carrier and coverage can't be overestimated.

SLIDE 35
Here's a series of slides that are going to go through carrier rates. Here is 24 ounces of carrier per ton. You can see the coverage on this is not all that great.

SLIDE 36
32 ounces of carrier per ton

SLIDE 37
50 ounces of carrier per ton

SLIDE 38
64 ounces of carrier per ton

There's huge difference in the coverage. Let's take a look at those one more time, going backwards this time. This is 64 ounces of carrier per a ton

SLIDE 39
50 ounces of carrier per ton

SLIDE 40
32 ounces of carrier per ton

SLIDE 41
24 ounces of carrier per ton. Certainly the lack of wetness is noticeable.

SLIDE 42
I did some fluorescent dye work as well. Taking a look at coverage on these potatoes. And again, you can see fairly decent coverage

SLIDE 43
This is from the dye work. This is the 64 ounces per ton and a clean undyed potato placed in the middle for contrast.

SLIDE 44
This is 48 ounces per ton with a clean undyed potato placed in the middle.

SLIDE 45
This is 32 ounces per ton with a clean undyed potato placed in the middle.

SLIDE 46
This is 64 ounces per ton. You can see the coverage on the potatoes as well as the belt.

SLIDE 47
This is 48 ounces per ton. There isn't as much coverage here.

SLIDE 48
This is 64 ounces per ton where the dye can be seen during the application process.

SLIDE 49
This is 40 ounces per ton, and there is noticeably less dye

SLIDE 50
64 ounces per ton under the UV light

SLIDE 51
And this is 40 ounces per ton. Big difference in amount of spray this coming through and in coverage.

SLIDE 52
Again, if the material is going to be used, it needs to get well distributed onto the potato tuber.

SLIDE 53
An applicator that was designed specifically for this purpose. This is copper , but I made several different forms. The easiest one is out of PVC pipe. The material is easy to work with cheap.

SLIDE 54
This is a fact sheet on this particular applicator. All of the parts list of supplies and measurements are in the included in it. The PVC applicators are far easier to deal with and can be made without having to sweat on the copper pipes.

SLIDE 55
Also included in this fact sheet as well is nozzle choice and calibration. What nozzles should be used at the PSI at three, four, six, eight nozzles per boom. This is based on how fast the unloading process is and is listed under the CWT per minute unloading rate. Calibrations are include for 40 and 60 ounces per ton carrier rates as I feel less than that can be ineffective.

SLIDE 56
In summary, for dealing with storage issues:

ventilate, but do it properly
manage the storage to the market that is the temperature and the cool-down rate
manage the parameters you can manage
manage around those that you can't.

SLIDE 57
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