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Tuber maturation and potato storability: Optimizing skin set, sugars, and solids

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This publication is one in a series of three relating to potato crop production in Wisconsin. Other issues pertain to growth and development and storage management.

Wisconsin farmers produce over 25 million cwt (hundredweight) of potatoes for fresh market, processing, chips, and seed each year. The farm gate value of the Wisconsin potato crop exceeds $200 million annually. The impact of potato on the state economy increases when considering the value added by processing potatoes.

To ensure a steady supply of raw product year-round, up to 80% of the potato crop is stored in climate-controlled warehouses. Typically, about 10% of the crop is lost to breakdown during storage. In 2000 and 2001, more than 20% of the stored crop was lost, costing Wisconsin potato farmers an estimated $32 million.

Maximizing the value of the stored potato crop in Wisconsin requires careful crop management going into storage. Better quality of potatoes going into storage improves the potential quality of potatoes coming out of storage. Storage losses are primarily due to shrinkage and spoilage. **Shrinkage** or shrink is the loss of moisture and carbon from the tubers through evaporation and/or respiration. **Spoilage** is the breakdown of tubers by pathogens in storage. Tuber diseases can spread quickly within a potato pile, leading to catastrophic losses.

Potatoes may make it through storage but end up being rejected by end users due to deterioration of quality during storage. Quality factors of the stored potato crop differ based on end use. Fresh market potatoes can be rejected for bruises and surface blemishes. Processing and chip potato quality factors include solid content, bruises, and fry or chip color. Seed potato quality factors include sprouting, presence of disease on tuber surfaces, and bruises.

Harvesting tubers at peak maturity favors good storability. Maturity refers to four distinct processes that occur as the crop approaches harvest (table 1). **Vine maturation** or senescence triggers tuber maturation. The tubers must undergo **chemical maturation** for optimal chip and fry color, **physiological maturation** for maximum yield and quality, and **physical maturation** to minimize skinning, shrinkage, and disease development during storage. Each process is described in this publication, along with recommended management practices that increase the likelihood of producing potatoes with good storability.

Potato vine maturation

Vine maturation occurs over the final 2 to 3 weeks of potato plant growth. Ideally, this corresponds with the final 2 to 3 weeks of the production season to allow for optimal crop yield and quality. As the plant matures, the leaves begin to senesce, photosynthesis decreases, and the movement of carbohydrates to the tubers declines. At this time, tuber bulking rates decrease, allowing tuber maturation to occur.

Growers can stimulate tuber maturation by using a nonselective contact herbicide to desiccate vines. Alternatively, nutrient and irrigation management must be designed to allow the vines to senesce naturally if vine desiccation is not used.

A key change in Wisconsin potato crop production has been the use of field management strategies that increase vine vigor before desiccation in mid-September. Delaying potato vine maturation with intensive nutrient, pest, and irrigation management increases tuber bulking and size. However, there are trade-offs to delaying vine maturation: it stimulates vigorous growth making desiccation difficult, it delays chemical maturity and skin set, and it leads to reduced storability.

Where potato vines formerly began senescing before the application of desiccants, they now remain vigorous well into September. As a result, the maturation process of potato does not initiate until vine desiccation. Potato tubers require up to 40 days for maturation, but recent production practices in Wisconsin have tried to squeeze maturation into a 20- to 30-day window. Delayed and decreased maturation is believed to have contributed to the increased storage losses of 2000 and 2001.

Potato tuber maturity

Tuber maturity refers to chemical, physiological, and physical maturity. Each of these maturity categories reflects a different process that occurs in the potato plant. Each category has a different effect on the storage quality of the crop or the ability of the tubers to withstand losses. Tubers that are chemically, physiologically, and physically mature are most likely to have excellent storability.

Chemical maturity

Process. Chemical maturity refers to the sucrose content within tuber tissues. The extent of chemical maturity reflects the movement of sucrose within the plant during the course of the growing season. Sucrose is of critical importance because it is the primary carbohydrate translocated from the leaves to the tubers. Sucrose is converted to starch, the primary storage carbohydrate, upon entry into the tubers of growing potatoes.

Table 1. Aspects of potato maturity that affect tuber storability and quality

	Vine maturity	Chemical maturity	Physiological maturity	Physical maturity
Characteristics	Leaves die back	Low tuber sucrose	High specific gravity	Skin set
Benefits	Promotes tuber maturity and storability	Leads to better chip and fry color	Favors high yields and better quality	Minimizes skinning, shrinkage, and disease
Management	Decrease availability of nutrients and water late in the growing season Kill vines 3 weeks before harvest	Monitor sucrose content before and after vine kill Harvest tubers when sucrose is at a minimum (<1.0 mg/g fresh weight)	Monitor specific gravity before harvest Harvest when specific gravity peaks	Kill vines 2 to 3 weeks before harvest Confirm sufficient skin set prior to harvest

Types of sugars

The three key sugars present in potato tubers are glucose, fructose, and sucrose. Glucose and fructose are **reducing sugars**. Reducing sugars react with free amino acids during frying, causing tuber tissues to turn brown or black. Sucrose is a **nonreducing sugar**; elevated concentrations do not immediately result in dark fry color. Once in the tuber, sucrose is either converted into starch or broken down into glucose and fructose.

The conversion of sucrose to starch begins shortly after tuber initiation and occurs rapidly, with little free glucose or fructose formed. As a result, the glucose and fructose content declines quickly to a minimal level during early growth of the tubers. (See box for details about the types of sugars and their importance.)

Expressing the concentration of sugars in tubers

Sugar concentration in tubers can be expressed as mg/g of tuber fresh weight (FW) or as a percentage of fresh weight. To change from one to the other, use the following conversion:
1 mg/g FW = 0.1% FW

As the potato plant matures, the vines begin to senesce, photosynthesis declines, and the movement of sucrose to the tubers slows. At the same time, the concentration of sucrose approaches minimal levels as it is quickly converted to starch upon entry into the tuber. Chemical maturity is achieved once sucrose concentrations reach a minimum. For processing and chipping potatoes intended for long-term storage, the sucrose concentration at chemical maturity is typically less than 1.0 mg/g fresh weight (FW).

While the plant is actively growing and the tuber is still bulking, sucrose is typically converted to starch. In storage, high concentrations of sucrose can break down and lead to elevated reducing sugars. High sucrose levels can result from harvesting chemically immature tubers or from the breakdown of starch. Tubers harvested during late bulking or during maturation typically have low glucose or fructose concentrations. If processed directly from the field, these potatoes will generally have good fry color due to low reducing sugar content regardless of sucrose concentration. Conversely, once tubers are in storage or have been subjected to stress events, sucrose is more likely to be converted into reducing sugars glucose and fructose. An accumulation of reducing sugars during storage will lead to poor fry color.

Consequences of harvesting chemically immature potatoes.

Tubers harvested before they're chemically mature will have elevated tuber sucrose concentrations when placed into storage. Higher sucrose concentrations can lead to increased reducing sugar concentrations and darker fry color, lowering the quality of chip and processing potatoes.

Longer preconditioning times. Chemically immature chipping tubers require longer preconditioning to reduce sucrose levels to <0.7 mg/g fresh weight to achieve acceptable quality during long-term storage. Preconditioning temperatures for potatoes are 55 to 57˚F. Longer preconditioning periods required by chemically immature potatoes will result in increased shrink (weight loss) and potential for disease development.

Preconditioning is less effective. The potential for manipulating tuber sugar concentrations in processing potatoes such as Russet Burbank, Freedom Russet, Bannock Russet, Millennium Russet, and others during storage is challenging. Preconditioning has smaller effects on tuber sucrose concentrations in russet potatoes in general compared to chipping potatoes. As a result, preconditioning periods required to decrease sucrose concentrations are much longer in processing russets compared to chipping potatoes, leading to unacceptable losses in shrink and risk of disease development in storage. Elevated sucrose concentrations in processing russets will likely remain higher in tubers harvested immature, leading to higher reducing sugar concentrations and poorer fry color. Chemically immature tubers also have shorter storage life, as senescent sweetening will begin earlier.

More susceptible to cold sweetening. Chemically immature chipping potatoes are more susceptible than mature tubers to cold sweetening, the accumulation of reducing sugars in response to cold temperatures. As a result, the set point, or minimum storage temperature, will have to be higher for chemically immature potatoes. Higher set points increase shrink due to increased tuber respiration.

Harder to recondition. If chemically immature tubers do develop high levels of reducing sugars, they will be more difficult to recondition.

High levels of acid invertase activity on stem ends. **Acid invertase** is the enzyme responsible for converting sucrose to reducing sugars. Acid invertase activity on the stem end of russet potatoes is typically higher than in the remainder of the potato tuber. The level of acid invertase activity depends on stress experienced during the growing season. Severe cases are called **sugar ends**, as the french fries have a darker fry color on the end of the tuber, typically the stem end. The sugars on the stem end of russet potatoes respond little to preconditioning practices in storage.

Monitoring chemical maturity.

Monitoring chemical maturity of chipping potatoes has been common practice for several decades, whereas russet potatoes for processing have rarely been monitored. Chemical maturity is determined by quantifying the sucrose concentration of the potato tubers. Chip potato growers typically begin monitoring sucrose concentrations the first week of August and continue sampling every 7 to 14 days until the crop reaches chemical maturity and is desiccated. (For details, refer to *Maintenance of Potato Processing Quality by Chemical Maturity Monitoring (CMM)* by Sowokinos and Preston.)

Sampling should be done in at least three to four locations within each field. Collect one midsized tuber (6 to 10 ounces) from six different plants at each location. Tuber samples must be processed within 24 to 48 hours of collection to minimize the potential for conversion of sucrose to starch or reducing sugars. Submit tubers that are whole and undamaged, as sugars change rapidly after cutting.

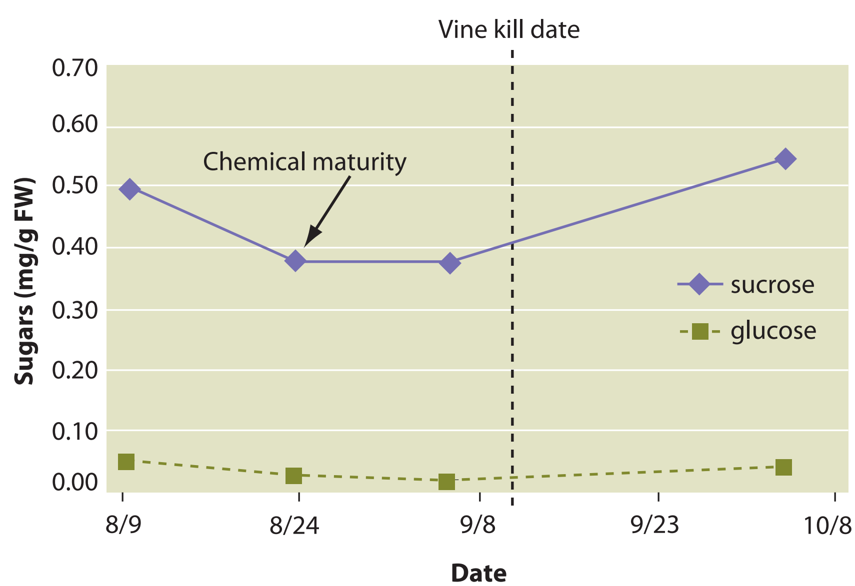
Quantification of sugar concentrations within potato tubers can be accomplished with several methods. The most commonly used method involves juicing potato tissue to determine the sucrose and glucose concentrations with a YSI 2700 biochemical analyzer (available from LSI Life Science; www.ysilifesciences.com or 800-659-8859).

Several chipping potato growers have equipment to monitor chemical maturity. In addition, crop consultants will determine tuber sugar concentration for a fee. Techmark, Inc. (www.techmark-inc.com or 517-322-0250) in Michigan is the closest consulting firm to Wisconsin that will process potato tuber samples for sugar concentrations.

Chemical maturation of chipping potatoes should be monitored before vine desiccation and harvest. Most chip potatoes are chemically mature by mid- to late August. Figure 1 shows chemical maturity levels for Dakota Crisp. In that study, sucrose concentrations declined to a minimum and were well below the critical level of 1.0 mg/g fresh weight. In contrast, glucose concentrations were low throughout the entire sampling period up until vine desiccation.

Vine desiccation in mid-September and the subsequent harvest triggered increased glucose and sucrose concentrations in early October. These sugars are typically reduced through preconditioning to allow for acceptable chip color out of storage.

Figure 1. Sucrose and glucose concentrations in Dakota Crisp tubers sampled directly from the field during August through September, 2005. Vine desiccant was applied 9/16.



The chemical maturity of processing russets is rarely monitored by commercial growers. Sugar concentrations of the bud and stem ends of russet and other long tubers are typically quite different, so sugar concentrations must be monitored separately (figure 2).

Sucrose concentrations of Russet Burbank were minimized by early to mid-September in both ends of the tuber, with concentrations being higher in the bud end. Glucose concentrations were minimized up until chemical maturity. However, glucose concentrations increased in the stem end of the tuber from the time of chemical maturity until harvest.

Drought and moisture stress can result in increased acid invertase activity, leading to the conversion of sucrose to reducing sugars once tubers reach chemical maturity. High concentrations of glucose accumulated in the stem end cannot be reduced through preconditioning.

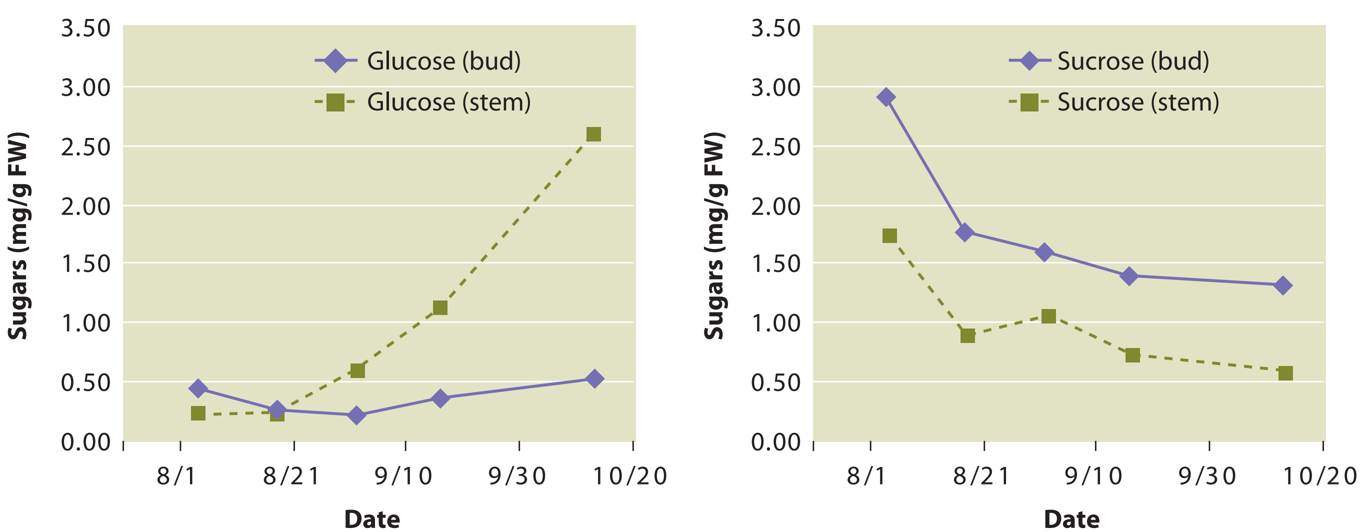
Managing for chemical maturity. Chemical maturity is managed by allowing the crop to mature. Chipping potatoes should be monitored for sucrose to make sure concentrations are kept below 1.0 mg/g fresh weight for Snowden and other varieties. Varieties differ in sucrose concentrations at chemical maturity. Some new varieties are not chemically mature until sucrose levels are reduced to 0.7 mg/g fresh weight or lower. (For variety-specific information, contact your state Extension potato specialist.)

New potato varieties such as Premier or varieties designated as "LS" have much higher sucrose concentrations at chemical maturity and harvest than traditional varieties such as Snowden. As a result, optimal sucrose concentrations at vine desiccation and harvest will be different than currently produced varieties.

Vine desiccants should be applied after potatoes are chemically mature and when tubers have finished bulking to optimize yield and minimize tuber sugar concentrations prior to harvest and placement in storage. Vine desiccation can lead to increased tuber sucrose concentrations following application and prior to harvest. Reducing sugars accumulated during this time are easier to metabolize during preconditioning in chemically mature tubers than in immature tubers.

Practices that delay crop maturity will delay chemical maturity and increase tuber sucrose concentrations in storage. Excess nitrogen, for example, can lead to increased vine growth, delayed tuber bulking, and ultimately higher tuber sucrose concentrations. Final nitrogen applications should be made within 80 to 85 days of crop emergence or at least 30 days prior to vine desiccation. No yield or quality benefits have been observed when nitrogen has been applied later than 45 days before vine kill.

Figure 2. Sucrose and glucose concentrations in bud and stem end of Russet Burbank tubers sampled directly from the field during August through September, 2005



Irrigation can also influence chemical maturity. Less frequent and more thorough irrigation 15 to 30 days prior to vine desiccation promotes tuber bulking and chemical maturation under good growing conditions. If conditions become hot and soil temperatures exceed 75ºF, more frequent irrigation may be necessary to reduce hill temperature and maintain tuber bulking. Allow vines to senesce naturally to promote tuber bulking. Irrigation should be continued through harvest, but be careful to avoid over-irrigation after vine killing.

Preventing over-maturation can be just as important as managing for chemical maturity. Over-maturation also leads to elevated sugar concentrations. Premature vine death due to inadequate fertilization, drought stress, early dying, or other causes can result in over-maturation of potato tubers and increased tuber sucrose levels. Long delays in harvest following desiccation can also lead to increased sugar concentrations, especially if temperatures approach freezing. Over-mature potatoes should be chipped or processed as soon as possible as they will have limited storage life.

Physiological maturity

Process. Physiological maturity refers to the state of the dry matter content of the potato tubers. Starch is the primary storage carbohydrate in potato tubers. Potatoes with high starch and low sucrose content generally have better processing characteristics and better attributes for fresh market potatoes. Starch and dry matter content continue to increase until potato tubers mature. Correspondingly, the specific gravity (or solid content) will reach a maximum as potatoes mature. A majority of sucrose is converted to starch or respired in the tubers during maturation until maximum solid content is reached.

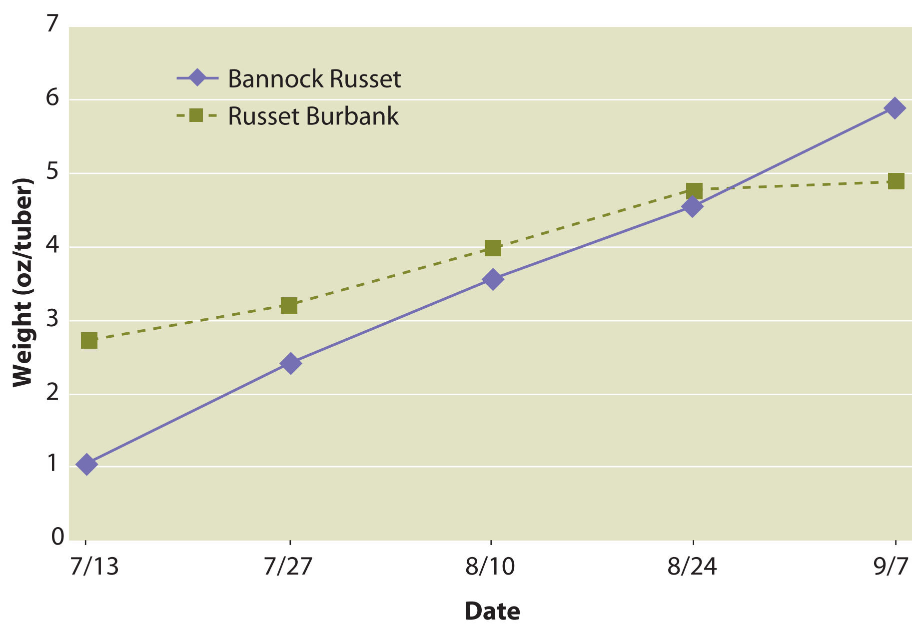
Consequences of harvesting physiologically immature potatoes. Harvesting potatoes before they reach physiological maturity will reduce yield because tubers haven't reached full bulking. In addition, physiologically immature potatoes will have reduced solid content, leading to reduced specific gravity. Lower solids mean poor processing quality and reduced prices if specific gravity does not meet minimum contract requirements. Lower specific gravities result in poorer end product quality as well.

Monitoring physiological maturity. Monitoring physiological maturity requires the measurement of the tuber's specific gravity. Determine specific gravity every 7 to 10 days until tubers reach a maximum or at the very least the minimum level specified by contract. In a 2005 test, Russet Burbank tubers reached maximum tuber size by the end of August, while Bannock Russet continued bulking into September (figure 3).

Correspondingly, Russet Burbank had reached maximum tuber specific gravity by the middle of August, but Bannock Russet specific gravity continued to increase until mid or late September, indicating later physiological maturity for Bannock Russet (figure 4).

Several methods are available for determining tuber specific gravity. Hydrometers are available from multiple sources. To use one, place a predetermined weight of potato tubers in a basket and suspend it from the hydrometer in water. The specific gravity is determined by estimating the level of the water on the scale. Hydrometers must be calibrated to accurately predict tuber specific gravity.

Figure 3. Average tuber size of Russet Burbank and Bannock Russet potatoes sampled from the field during July through mid-September, 2005



Alternatively, specific gravity can be determined by measuring the weight of potato tubers in air and in water. Specific gravity is calculated by:

Specific gravity = weight in air / (weight in air – weight in water)

Automated systems for determining specific gravity are available at the Hancock Agricultural Research Station (www.ars.wisc.edu or 715-249-5961) and on several other farms.

Figure 4. Russet Burbank and Bannock Russet specific gravity during August and September, 2005

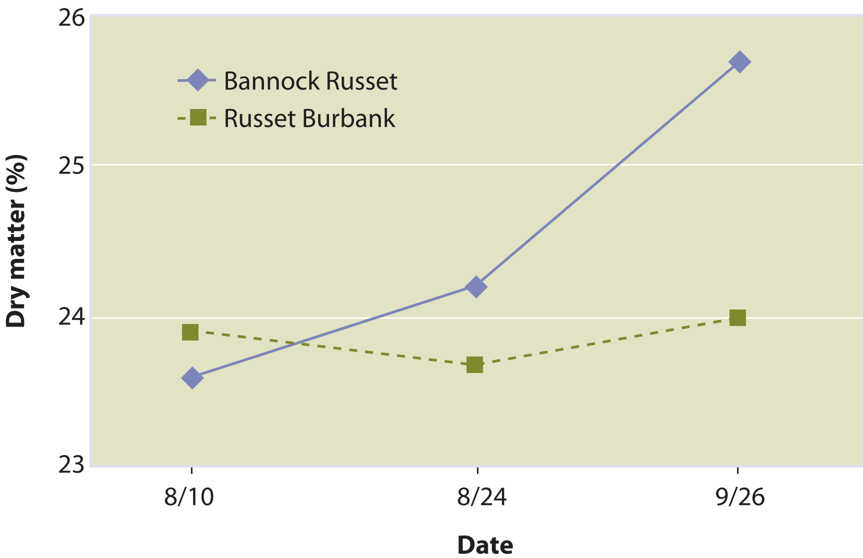
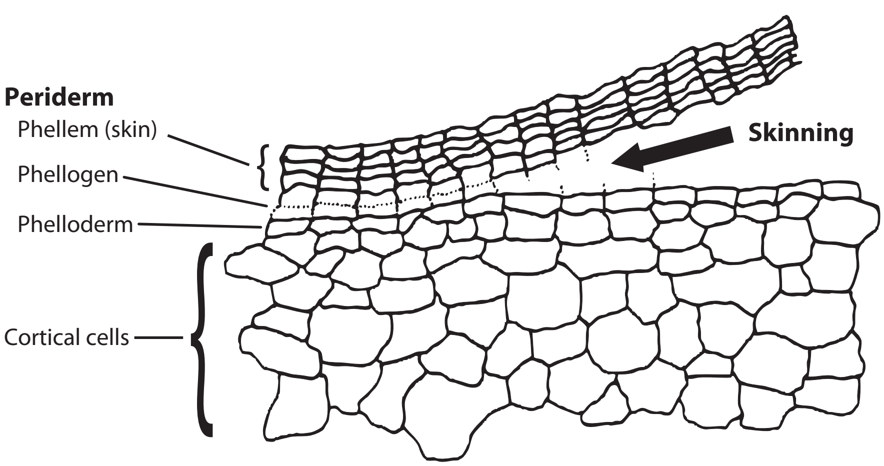


Figure 5. A diagram of the potato periderm showing the phellem, phellogen, and phelloderm and underlying cortical cells. Skinning occurs when physical forces cause phellogen cells to break and the phellem to peel off.



Adapted from E.C. Lulai (2002). The roles of phellem (skin) tensile-related fractures and phellogen shear-related fractures in susceptibility to tuber skinning injury and skin-set development. *Am. J. Pot. Res.* 79: 244. Reprinted with permission.

Managing for physiological maturity. Managing for physiological maturity simply requires allowing the crop to mature. Delayed crop maturation due to excess nitrogen application can prevent physiological maturity and result in decreased specific gravity. Vine desiccation can promote physiological maturity and result in slight increases in specific gravity.

Physical maturity (skin set)

Process. Physical maturity relates to skin set (resistance to skinning injury) on potato tubers. Potato tubers expand rapidly during late tuber bulking. The skin, which is part of the periderm, must be capable of expanding with the growing tuber. As the crop starts to mature, potato tubers stop expanding and the skin starts to set, binding to underlying tissues. Skin set is a key process of potato maturation that protects the tuber from damage during harvest, handling, and storage. Skin set typically requires 40 days, but most crops are harvested within 20 days of vine desiccation, well before skin set.

The periderm is composed of three layers of tissue: the phellem, phellogen, and the phelloderm (figure 5). The phellem, or outer tissue, is referred to as the skin. The phellogen is a thin region of immature, meristematic tissue (rapidly dividing cells). The phelloderm is the tissue adjacent to the starch-storing cortical tissue inside the tuber.

Production of new cells by the phellogen enables the skin to expand as the tuber grows. These dividing cells hold the skin in place but have little strength during tuber bulking. The skin of a growing tuber is easily damaged or removed by rubbing your fingers over the surface of the tuber (figure 6).

Skin set provides resistance to skinning and increased resistance to water loss. Skin set and the increased resistance of tuber periderm to skinning is primarily due to strengthening of the phellogen, which occurs over a 2- to 5-week time frame. The cell walls of the phellogen become stronger during maturation, increasing the tuber's resistance to physical damage during harvest and handling (figure 5). Strengthening of the cell walls of the phellogen is critical as skinning damage is the result of phellogen cell breakage.

Suberin is a complex biopolymer that is integrated into the phellem or skin of the tuber. Waxy materials are embedded into the suberin matrix and restrict water loss through the periderm. Suberin and associated waxes are present in the periderm throughout the growth of the tuber, but the ability of the periderm to minimize water loss increases as the tuber matures. Suberization is also critical for preventing infection of the tubers by fungi and bacteria that cause tuber rot. (See sidebar for more details about suberin.)

Figure 6. Skinning injury caused by the harvest of immature potatoes

About suberin

Suberin is mainly composed of lignin-like and fatty acid-based biopolymers that form a barrier that protects the potato from pathogen attack. Soluble waxes embedded in the suberin prevent water loss and help the tuber remain firm. The process by which the potato lays suberin down inside the walls of its cells is called suberization. The phellem (skin) is suberized, forming a protective barrier around the tuber. When skin is removed from a potato, a wound response results in suberization of the cells underneath the skinned area. This "closing layer" is formed in a few days and provides temporary protection for the tuber. Eventually, a new "wound" periderm is formed underneath the closing layer to provide an organized series of suberized cells, the wound phellem, for permanent protection. Suberization requires oxygen and can be inhibited by anaerobic conditions.

Consequences of harvesting physically immature potatoes. Physically immature potato tubers are more vulnerable to skinning due to poor or failed skin set. Harvesting potatoes that are physically immature can lead to increased damage to the periderm during harvest.

Physically immature potato tubers take longer to form the closing layer and develop a wound periderm than mature tubers. Increased periderm damage and longer time required for wound healing means that immature tubers are more susceptible than mature tubers to infection by fungi and bacteria once they are placed in storage.

Physically immature tubers have higher respiration rates compared to mature tubers. Higher respiration rates lead to elevated CO_2 and less O_2 in storage. Higher respiration also generates more heat in the potato pile. The combination of high CO_2 levels, low O_2 levels, and increased temperatures creates an ideal environment for disease development, leading to tuber infections and increased spoilage. These same conditions also inhibit suberization and the formation of closing layers over tuber wounds in storage.

Immature potato tubers have higher evaporative water loss than mature tubers, and water loss due to evaporation leads to loss in turgidity within cells. Decreased turgidity increases tuber vulnerability to damage by pressure bruise. Pressure bruised areas wound-heal poorly, lose further water vapor at the bruise site, and frequently develop pressure bruise-induced blackening of tuber tissue.

Skinned areas heal by forming a wound periderm to protect the tuber from infection by bacteria and fungi and to prevent loss of water. Wound periderm usually has different coloration than native periderm and little to no russeting. Excessive wounding from skinning injuries of immature tubers will decrease value of fresh market potatoes due to the influence of appearance on grade. Skinning can cause dark shrunken areas on processing potatoes, leading to problems when tubers are peeled.

Monitoring physical maturity. Monitoring physical maturity requires measurement of the force required to remove the potato periderm. The easiest way to assess skin set is by rubbing your thumb against the skin to try to remove the periderm. On immature tubers, the skin will readily slough off. Mature tubers require greater force to remove the skin. Air-dry tubers for several hours before using the thumb test.

Skinned potatoes being loaded into a storage facility.

Managing for physical maturity. Physical maturity is managed by desiccating potato vines 21 days before harvest. Limit irrigation during this period to minimize free water surrounding tubers. Maintain soil moisture above the critical level to keep tubers hydrated to prevent bruising.

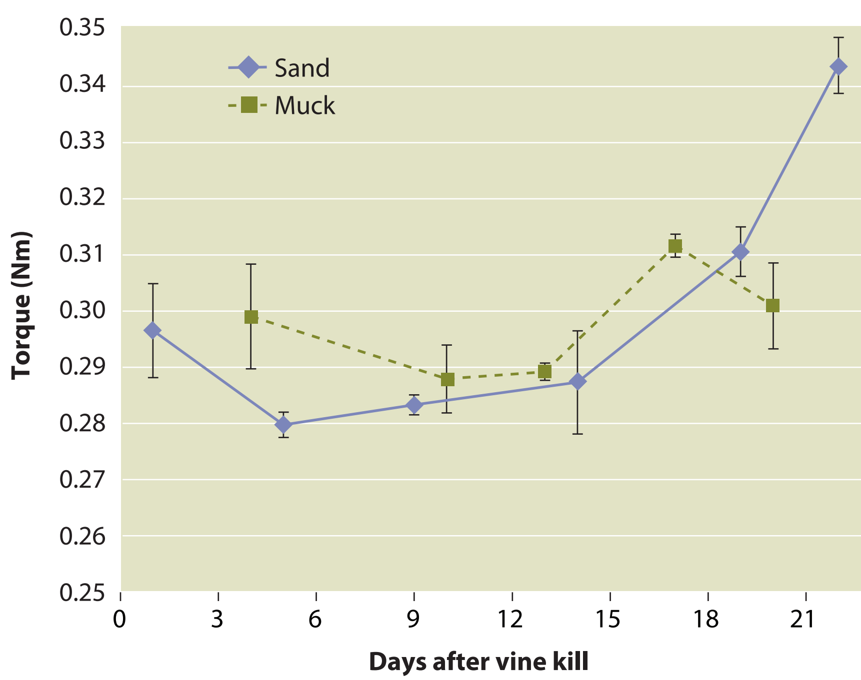
In a study, time after vine desiccation increased physical maturity as measured by the force required to remove the periderm (figure 7). Timing vine desiccation to when potato vines have naturally begun to senesce will increase physical maturity. Practices that delay vine senescence, such as excess nitrogen or delayed nitrogen application, will delay physical maturity and increase susceptibility to skinning. In this particular example, potatoes grown on sand soil physically matured more quickly than potatoes grown on muck.

Potato types and varieties within types differ in their susceptibility to skinning. For example, Bannock Russet is more vulnerable than Russet Burbank, and Villetta Rose is more vulnerable to skinning than Red Norland. Potatoes require a minimum of 3 weeks after vine dessication to set skin, with reds being more vulnerable to skinning than russet or round white potatoes.

Potatoes that suffer excessive skin damage because they are harvested while still immature require special post-harvest care.

- Remove field heat as quickly as possible and maintain storage temperature at 55°F to promote wound healing and to minimize potential disease development.
- Initial air speed should be managed at 1 cubic foot per minute per hundredweight (cfm/cwt) to equalize temperature of potatoes within the potato pile and to remove free water.
- Target a temperature difference, or ΔT, between the top and the bottom of the pile of no more than 1 to 1.5°F. Maintain humidity at 95% to minimize water loss from tubers and the potential for pressure bruise.
- The storage atmosphere should be purged with outside air at least once a day to prevent excess CO_2 accumulation. The duration of purging will vary depending on storage volume, air speed, and outside versus inside air temperature. Elevated CO_2 delays development of the closing layer and promotes the development of anaerobic bacteria, which can infect potato tubers and cause decay. Delta T of 1.0 to 1.5°F ensures evaporation of free water from tubers while maintaining high enough relative humidity to prevent excessive dehydration of skinned tubers.

Figure 7. The amount of force (torque) required to remove tuber periderm of Red Norland potato skins following vine desiccation in 2007. Tubers were grown in muck and sand soils and harvested 3 weeks after vine kill.



Overall crop management

The goal is to manage potatoes so that chemical, physiological, and physical maturity occur simultaneously. In reality, the timing of the three phases of maturation cannot always be coordinated because of slight differences in the processes influencing their development. However, the following management factors influence all aspects of tuber maturation and must be implemented for successful long-term storage.

Tuber maturation is linked to the maturation of the entire plant. Keeping the vines green and actively growing up until the time of vine desiccation and harvest will delay tuber maturation and result in harvest of immature potato tubers. Conversely, if the plant matures too early and the vines senesce prematurely, the crop will not reach its yield potential and tubers may become over-mature.

The crop must be managed to promote the maturation of the potato plant at the appropriate time. Ideally, vines should begin to senesce, with older leaves turning chlorotic 14 to 20 days prior to vine killing. This promotes maximum translocation of carbohydrates from the crop canopy to the tubers, resulting in maximum specific gravity and yield and initiation of skin set. In addition, natural plant senescence should reduce the flow of sucrose to the tubers, allowing conversion to starch and minimizing tuber sugar concentrations.

The three primary means of managing plant maturation:

Crop fertility, specifically nitrogen content, has large effects on canopy growth and development. Nitrogen fertilizer rates must be optimized to maximize yield, but excess nitrogen applications should be avoided to allow natural senescence of plants leading up to vine desiccation.

Nitrogen status within the crop should be monitored with petiole (leaf stem) sampling, and supplemental fertilizer should be applied if necessary to ensure crop yield goals are achieved. For more information, see Nutrient Application Guidelines for Field, Vegetable, and Fruit Crops in Wisconsin (A2809) and Commercial Vegetable Production in Wisconsin—2009 (A3422).

Supplemental fertilizers should no longer be applied 80 to 85 days after crop emergence or 40 to 45 days before vine desiccation.

Irrigation can also be manipulated to promote natural senescence of vines. During late bulking and plant maturation (late August or early September) irrigate less frequently and at amounts just sufficient to moisten the potato root zone. Adjust irrigation amounts as vines senesce to reflect the diminishing evapotranspiration of the declining canopy.

Vine desiccation is the final step for promoting maturation of potato tubers. Vine desiccants should be applied at least 21 days before the intended harvest date to promote tuber skin set and maximum specific gravity.

Vine desiccation often increases sugar content of tubers but is necessary to promote skin set of stored potatoes. In addition, vine desiccation prevents late blight from infecting tubers, which is crucial for successful storage. Vine desiccation is the primary method of crop maturation in WI. In other regions of the U.S. where vine desiccation is not used, management of fertility, irrigation, and harvest timing are critical.

Vine desiccants vary in their relative activity. Some desiccants kill vines within 12 to 24 hours, while others require several days. Follow label directions for effective potato vine desiccation.

Citations

Brandt, T. and N. Olsen. 2006. Storage requirements for new varieties. Proc. Idaho Potato Conf.

Lulai, E.C. 2002. The roles of phellem (skin) tensile-related fractures and phellogen shear-related fractures in susceptibility to tuber-skinning injury and skin-set development. *Am. Potato J.* 79:241–248.

Lulai, E.C., and T.P. Freeman. 2001. The importance of phellogen cells and their structural characteristics in susceptibility and resistance to excoriation in immature and mature potato tuber (*Solanum tuberosum* L.) periderm. *Ann. Botany* 88:555–561.

McKenzie, M.J., J.R. Sowokinos, I.M. Shea, S.K. Gupta, R.R. Lindlauf, and J.A.D. Anderson. 2005. Investigations on the role of acid invertase and UDP-glucose pyrophosphorylase in potato clones with varying resistance to cold-induced sweetening. *Am. J. Potato Res.* 82:231–239.

Nelson, D.C., and J.R. Sowokinos. 1983. Yield and relationships among tuber size, sucrose and chip color in six potato cultivars on various harvest dates. *Am. Potato J.* 60:949–958.

Ojala, J.C., J.C. Stark, and G.E. Kleinkopf. 1990. Influence of irrigation and nitrogen management on potato yield and quality. *Am. Potato J.* 67:29–43.

Olsen, N. 2004. Sugar and starch and everything nice. The Spudvine. University of Idaho Extension: Blackfoot, ID, September 2004.

Sabba, R.P., and E.C. Lulai. 2002. Histological analysis of the maturation of native and wound periderm in potato (*Solanum tuberosum* L.) tuber. *Ann. Botany* 90:1–10.

Sabba, R.P., A.J. Bussan, R.L. Hughes, B.A. Michaelis, M.J. Drilias, and M.T. Glynn. 2007. Effect of planting and vine-kill timing on sugars, specific gravity and skin-set in processing potato cultivars. *Am. J. Potato Res.* 84(3):205–215.

Sowokinos, J.R., and D.A. Preston. 1988. Maintenance of potato processing quality by chemical maturity monitoring (CMM). Minnesota Agric. Exp. Sta. Bulletin No. 586-1988. 11 pp.

Sowokinos, J.R., C.C. Shock, T.D. Stieber, and E.P. Eldredge. 2000. Compositional and enzymatic changes associated with the sugar-end defect in Russet Burbank potatoes. *Am. J. Potato Res.* 77:47–56.

Resources

Idaho Center for Potato Research and Education: http://www.ag.uidaho.edu/potato/

Potato Association of America: http://www.umaine.edu/paa/

Wisconsin Potato & Vegetable Growers Association: http://www.wisconsinpotatoes.com/index.html

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