Potato Tuber Sugar Concentration Monitoring
A practical discussion

By Todd Forbush

I remember looking at the 11,000 cwt bulk potato pile in April of 1985. A trusted friend was about to spread these potatoes over his fields prior to spring planting. A year’s worth of work wasted because the chip color had deteriorated below the level of acceptance. And though the potatoes were in great physical shape, there was no home for these potatoes in the marketplace.
I remember thinking, “What a waste. There has to be some explanation…some way to solve this problem.” But there was not, and his crop was a loss. Based on what we know now, that did not have to be the case.

POTATO RESPIRATION
The potato tuber produces sugar from the starch stored in it for respiration and survival during the storage process. The respiration takes place on the cellular level based on the following equation:

\[ C_6H_{12}O_6 + 6 O_2 = 6 CO_2 + H_2O + Energy. \]

Simply stated, the potato produces the sugar to respire and survive. The level of stress prior to storage and during storage increases the respiration rate of the potato, thus increasing the need of the six-carbon sugar glucose that is required for respiration. This sugar has one major side effect: poor process quality when the potatoes are fried.

MONITORING SUGAR
The practice of monitoring potatoes for tuber sugar concentration is not a new topic. The landmark research work on this topic was done by Dr. Joe Sowokinos, Duane Preston and their staff at the USDA Red River Valley Agricultural Research Center potato worksite in East Grand Forks, MN.
The “Maintenance of Potato Processing Quality by Chemical Maturity Monitoring” bulletin, published by this group in 1988, served as the initial extension communication on potato tuber sugar monitoring and is still valid today. This work promoted the cultural practice of monitoring the sugar concentration both pre-harvest and throughout storage to observe the process quality for potato chip processing.
Adoption of that practice has led to some form of tuber-sugar-concentration monitoring being employed for many of the potatoes grown and stored for both potato chip and french fry production around the world.

PRACTICAL RETURN
The incorporation of any new practice or technology in a business must first pass the ROI litmus test. The question to be asked: what is the practical return on investment, or what critical management decisions will the practice or technology application influence in this business? The return for sugar monitoring is primarily in the areas of potato inventory management and potato storage ventilation system operation.
INVENTORY MANAGEMENT
Inventory management is enhanced by placing a processing value on the crop at all times during storage. This allows marketing personnel to determine which lots in inventory will meet the processing specifications of the customer. This information is useful when determining which lots should be processed to maximize profit from the stored crop.

MANAGEMENT DECISIONS
The storage manager has the job of monitoring the storage daily to make certain that the temperature, humidity, CO2 levels, and fan operation for the storage are set properly to meet the tubers needs. These storage variables are critical to conditioning of a crop for that will be used for potato chips or french fries.
The proper settings are dependent on variety, growing season variations, market timing and a number of other factors. The level of the tuber sucrose and glucose provide benchmarks for how the tuber is responding to the storage environment. These benchmarks assist in decision-making based on the length of time the crop has been in storage as well as the current state of the crop.

THE PRECONDITIONING
The first decision the storage manager makes after a crop is in storage is whether it will require some conditioning prior to cool-down. If there is excessive sugar in the crop, it is recommended to hold the temperature of the crop at the suberization temperature, generally from 53 to 60 F temperature range until the sugar levels have dropped to an acceptable range for the variety.
Sometimes excessive sugar is a result of disease pressure in the field. This type of sugar accumulation is also associated with dead tissue within the tuber. Most disease-related sugar accumulation is very difficult to remove with pre-conditioning. It is critical to determine the reason for sugar accumulation prior to cooling the potato crop in storage to avoid “locking in” sugar that cannot be easily removed from the tuber while holding and reconditioning.

COOL-DOWN, HOLDING
The next determination is how much to cool the crop and the rate of cooling to be used. The answer will be based on the sugar concentration, the variety in storage and the intended storage duration. The manager needs to consider the susceptibility of the specific variety to cold-induced “sweetening.” This is a stress response made by the tuber when it is held at colder than optimum temperatures. If, instead, the crop is cooled to the ideal temperature, the sugar concentration will stabilize at a low level, and the process quality will be acceptable.
If the temperature drops below the optimum temperature, the sugar will begin to accumulate, as depicted in the tuber sugar readings. This is an indication that this particular crop needs to be stored at a temperature warmer than that selected in the initial cool-down phase.
The CO2 concentration of the storage atmosphere should be monitored during holding. Extreme cold or unseasonably warm weather will influence the operation of the ventilation system in maintaining the proper temperature. This may cause an increase of
the CO₂ concentration in the storage atmosphere. High CO₂ levels will result in stress on the tubers, causing sugar to accumulate with a subsequent detrimental effect on process quality. Proper air inlet management with a carefully designed CO₂ flush will maintain the process quality during widely fluctuating outside temperature conditions. Tuber sugar accumulation due to high CO₂ is a reversible stress if the CO₂ levels are lowered to an acceptable level prior to permanent tuber tissue damage.

RECONDITIONING
Prior to shipment of the crop for processing, it is sometimes necessary to remove any sugars that have accumulated during storage. It is important to determine the cause of the sugar accumulation in order to fully understand how to remove this sugar prior to shipment. The practice of reconditioning involves warming the crop to a temperature above 50 F (10 C), thus increasing the respiration rate of the tuber for sugar removal. This practice is viable if the reason for sugar accumulation is that the crop was held at a temperature below optimum. The practice is not appropriate, however, if the reason for sugar accumulation is CO₂ stress.
When reconditioning a crop for market, the storage manager should review the sugar profile of the tubers throughout storage, comparing this to the storage atmosphere in order to isolate the stress the tuber has been exposed to in storage. This will lead to the selection and implementation of a ventilation strategy that will meet the needs of the crop, thus returning the crop to marketable quality.

SENESCENCE SWEETING
Tubers that experience senescence sweetening, sugar accumulation as a result of storing potatoes past the ideal timeframe for the crop, cannot be reconditioned simply by increasing temperatures.

However, there are numerous examples where a lot of potatoes has been successfully processed into french fries or potato chips after the onset of senescence sweetening. These tubers often exhibited an increase in the 12-carbon sugar sucrose prior to an increase in the six-carbon sugar glucose. Upon noting the increase in sucrose, the crop can often be successfully processed within one to two weeks of the initial increase of sucrose with acceptable process quality.
The execution of this marketing strategy requires diligence in sugar monitoring during the later months of storage. The practice of sugar monitoring on a weekly basis will increase the effectiveness of this strategy during critical times in the storage season. Tuber sugar monitoring programs assist producers to achieve the goal of processing all potatoes put into storage by matching potato quality, storage environment and market demands.
As tuber sugar information is combined with information learned through enhanced production and storage practices, as well as increased understanding of our markets, the results are not only improved storage success but also higher profits for both the grower and processor.