THE CASE OF THE BRUISED POTATO

Everybody loses if the potato bruises.

Harvest is where everything that has been put into the crop comes together. It is the culmination of months of investment in soil preparation, feeding, watering, protecting and nurturing. Harvest for many growers is the last, critical piece of the puzzle, where value is finally realised.

Damaging the potatoes during harvest is surely snatching defeat from the jaws of victory!

Physical damage not only reduces eating quality of the tubers, it increases water loss and makes tubers more susceptible to rots and disease. In some cases, damage can make potatoes completely unsuitable for the target market.

External injuries are obvious. These include cuts as well as shatter bruises, which appear as cracks on the tuber skin. The cracks can extend into the core of the tuber, making an easy entry point for fungi and bacteria.

Skinning can also occur, where potatoes are harvested before the skins have fully matured and hardened. Rubbing by machinery, soil clods or simply other tubers removes the outer layer of skin. As with cuts, this makes it easier for pathogens to gain entry, as well as allowing dehydration.

However, internal bruising – blackspot – is harder to detect. Not only is blackspot not visible from the outside, but the damage does not appear immediately, rather developing over time.

WHAT IS A BRUISE?

Potato bruises develop due to impacts that either break the cells apart (shatter bruise) or rupture the cell membranes (blackspot).

While shatter bruises are straightforward to understand, blackspot is a little more complex.

Phenolic compounds inside potato cells are normally kept separated from reactive enzymes by internal cell membranes. If the membranes are ruptured, the two mix together and oxidise (Figure 1). Oxidation of the compounds that develop (ortho-quinones) ends in formation of the pigment melanin – essentially the same pigment that tans our skin and colours our hair and eyes. This is why bruises develop the black-brown colour we are so familiar with.

The potato skin is made up of relatively small, corky cells that resist damage. However, the swollen, starch laden cells that make up the pulp are more fragile. As the force of the impact

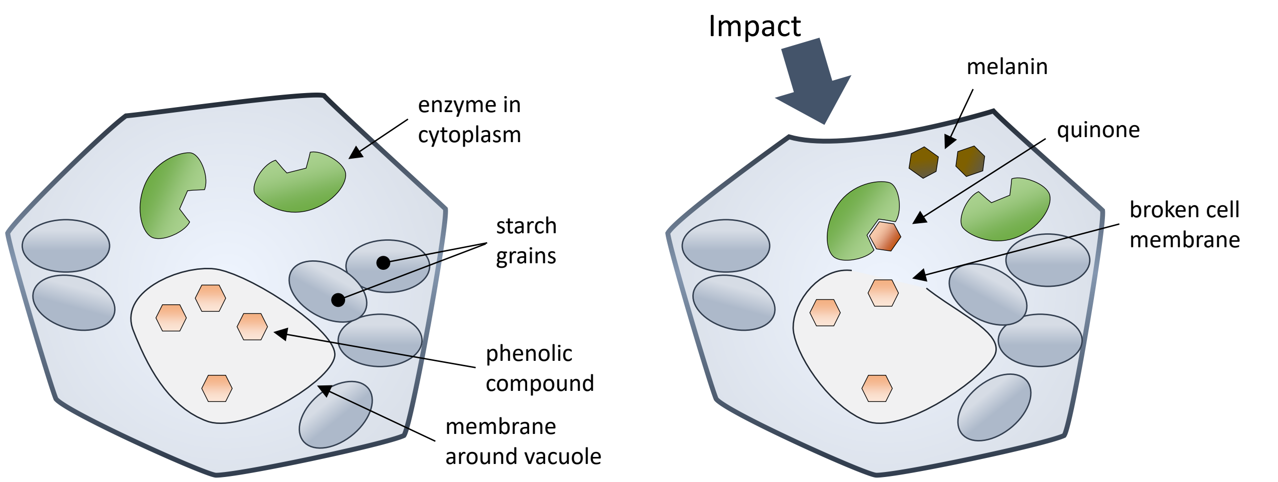


Figure 1. Intact potato flesh cells (left) contain phenolic compounds and oxidising enzymes, kept separate by internal cell membranes. An impact (right) can rupture this internal membrane, allowing mixing. Through oxidation, this eventually gives rise to the dark compound melanin, typical of blackspot.

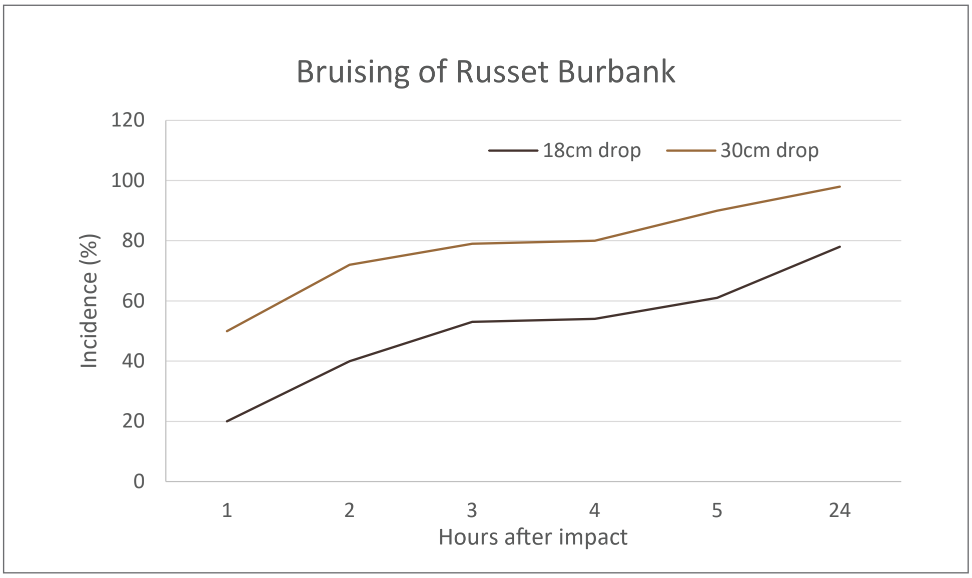


Figure 3. Blackspot development in Russet Burbank potatoes. Data extracted from Olsen and Thornton.

Figure 2. Blackspot development after 1, 2, 3 and 4 hours.

transfers from the outside to the inside of the tuber, it is the membranes of these cells that fracture most easily.

The reaction that produces melanin is not instantaneous, so bruises continue to darken over hours or even days (Figure 2). Initially, the damaged area develops a pinkish colour – possibly due to formation of ortho-quinones from the oxidised phenolics. This gradually oxidises into melanin, with the intensity of colour directly relating to the amount of phenolics and enzymes initially present in the cells.

Just as phenolic content varies between cultivars, so does the speed at which the bruise expands and darkens. Temperature and impact force also play a role. For example, Olsen and Thornton (University of Idaho)[1] found that bruises developed more slowly on Russet Burbank than Ranger Russet, and more slowly at cold temperatures than warmer ones. Despite this, most internal bruising became obvious within 3-5 hours of impact (Figure 3).

WHAT IS THE IMPACT THRESHOLD OF POTATOES?

Resistance to both shatter bruises and blackspot varies considerably between cultivars. The issue is compounded by factors such as soil moisture, temperature and specific gravity. So, for example, high specific gravity reduced bruising susceptibility in Snowden, but increased susceptibility in Russet Burbank and Atlantic[2].

Depending on their structural qualities, a variety may be relatively resistant to blackspot but susceptible to shatter, or vice-versa. For example, Russet Burbank is generally less easily damaged than Ranger Russet, while Shepody and other chipping varieties may be resistant to blackspot but susceptible to shatter bruising[3].

Temperature is also important. In general, temperatures between 12 and 18°C are often considered best for harvesting potatoes. Potatoes are less susceptible to bruising at such moderate temperatures than if they are either hot (>25°C) or cold (<12°C). This is reflected in the drops that can be tolerated.

Temperatures of dry soils are more likely to approach air temperatures; under warm conditions, soil (and the tubers it contains) can be cooled through more frequent irrigation.

Irrigating a few days before harvest also ensures tubers are well

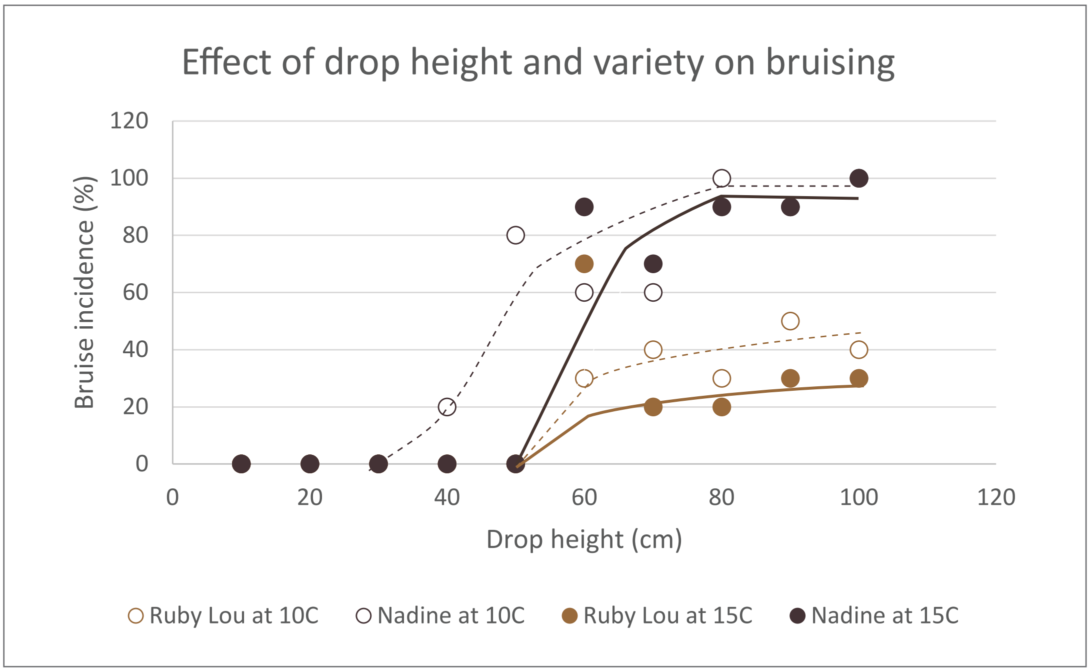


Figure 4. Incidence of bruising of Nadine and Ruby Lou potatoes dropped 10–100cm at either 10°C or 15°C. Lines indicate approximate best fit to data, except for the outlying value at 60cm for Ruby Lou. Data from Dawson and Johnstone, 2016.

hydrated, another factor that reduces susceptibility to bruising. However, there is a downside, as very high levels of soil moisture can make potatoes more susceptible to shatter bruising. The general recommendation is that soils should contain 60–80% available soil water at harvest.

Mathew and Hyde[4] estimated that the drop heights (onto steel) that were likely to cause a blackspot bruise in 10% of Russet Burbank tubers were 25, 30 and 50mm at tuber temperatures of 10, 15.5 and 21°C respectively. While this suggests that 21°C is optimal for harvest, the risk of increased disease at this temperature (and higher) likely outweighs any possible benefits from reduced blackspot.

Western Australian researchers[5] conducted similar tests on Ruby Lou and Nadine potatoes. One of the aims was to link bruise damage at 10 and 15°C to impact forces recorded using a "SmartSpud" (Sensor Wireless Inc.) datalogger. The SmartSpud contains an accelerometer and is used to record impacts during harvest and handling.

More on the SmartSpud, and other similar devices, on p25.

In the WA work, Nadine proved to be more easily bruised than Ruby Lou, with a trend to increased damage at 10°C compared to 15°C (Figure 4). One thing that is clear from these results is the increased bruising of both types, regardless of temperature, once heights exceeded 50cm. This corresponded with a value of 218G recorded with the SmartSpud. In contrast, Royal Blue tubers were more susceptible to bruising than either of these other varieties, with 10% of tubers damaged by a mere 30cm drop.

WHAT CAN I DO TO REDUCE RISK?

LOTS! There are two broad strategies for preventing blackspot:

1. Improve resistance to damage and

2. Avoid mechanical injury.

Elements of these strategies begin even before planting[6].

Improve resistance to damage

- Choose varieties with low susceptibility to bruising
- Don't over fertilise with nitrogen, especially late in the season: High vine nitrate readings are associated with increased susceptibility to blackspot
- Manage the crop to keep it as uniform as possible (e.g. through effective management of irrigation and fertiliser)
  - Uneven growth will result in under mature/overmature tubers, which are more prone to damage
  - Uniform stands also mean uniform flow through the harvester, reducing impacts on hard surfaces
- Control diseases that can cause premature vine death, as affected crops will have varying levels of maturity
- Kill tops before more than 50% of vines have died and wait at least 14 days before harvesting
- Avoid harvesting during hot conditions; consider harvesting in the early morning, when the air and soil are coolest
- Ensure soil is moist at harvest,

Figure 5. Devices for measuring impacts during potato harvest and packing: From left the Series 500 IRD (Techmark, USA), TuberLog (Esys, Germany) and Mikras (Esys, Germany)

especially if the weather is hot

- Well hydrated potatoes are less easily bruised
- Irrigation will drop the soil temperature below that of the air, cooling the tubers and reducing blackspot susceptibility
- Irrigation helps soften clods
- Damp soil will move more easily through the harvester

- If harvest must be carried out at high temperatures, consider how the tubers can be cooled to remove field heat
  - If potatoes stay warm during transport to a processing facility or storage, moisture loss can be high and diseases such as bacterial rots increase dramatically
  - Tubers that remain warm are physiologically older, reducing the quality of seed crops

Avoid mechanical injury

- Use cover crops or rotations that improve soil organic matter and deep rip to break up hard pans, as this will reduce crust formation and creation of damaging clods
- Further reduce clod formation by avoiding ploughing, discing or cultivating soil while wet
- Remove rocks and stones from the field
- Angle the digger blade at the front of the primary conveyor so that tubers are lifted onto the chain/web, not jammed into it
- Adjust the harvester speed so that the conveyors are kept around 85% full
  - If speeds are too slow, tubers will pile up and be forced against the sides
  - Too fast and tubers can roll around, hitting more hard surfaces
  - Suitable conveyor speed to ground speed ratios are estimated at 1.0 to 1.2 in sandy soil, but 1.2 to 1.5 in heavier soil[4]
  - Adjust other conveyors according to yield, increasing speed if picking up a windrow, while minimising rollback of tubers
- Cover conveyor support bars with padding to reduce impacts
- Use deflectors to divert tubers away from the sides of the de-viner, chain link ends and sorting table
- Minimise use of agitators and conveyor shakers to dislodge soil
- Minimise drops between different conveyors, particularly from the end of the boom conveyor into the truck, trailer or bins

The easiest way to find out where damage could be occurring is using an impact recorder, such as the SmartSpud already noted. Once identified, the drop may be reduced and/or cushioning added. Running the recorder through the line again can show whether the modification has been successful.

OK, I SEE THE VALUE - BUT WHAT IMPACT RECORDER SHOULD I GET?

The SmartSpud is not the only such device on the market, nor is this new technology, having been around since the 1990's.

The original impact recording device or "IRD" (Techmark USA) was a sphere designed to simulate an apple or onion. (Figure 5) This device is now sold in a range of shapes and sizes, and can be custom made to resemble anything from a blueberry to an egg to large processing potato (https://www.techmark-inc.com/impact-recording-device---ird.html).

Another option is the TuberLog (Martin Lishman) (Figure 5). Simlar to the SmartSpud, Tuberlog consists of an accelerometer embedded in a synthetic case that mimics the size, shape, density and movement of a ware potato. One difference between the TuberLog and other devices is that data is transmitted instantly via bluetooth, making it easy to see exactly where the damaging impact has occurred.

A final potential candidate is the Mikras logger (Figure 5). In this case the logger is supplied in a simple case. The user hollows out a cavity in whatever product is being handled, whether an apple, carrot, cucumber or potato. The advantage of this is that the user is measuring real impact on an actual potato. The disadvantages are that A. Not being brightly coloured, the device may be difficult to find and B. The "casing" needs to be replaced very often.

A group of German researchers compared these devices[7]. Interestingly, the IRD, TuberLog and Mikras (inserted in a synthetic case) all overestimated impacts onto a metal plate compared to the Mikras sensor implanted in an actual potato. However, the artificial potatoes were fairly accurate when dropped onto PVC or rubber cushion.

The SmartSpud recorded both fewer impacts and smaller impact values than the other devices, suggesting this device may actually underestimate potential impacts.

All of the impact recorders could provide information about where impacts were occurring during harvest and packing.

However, the authors noted that each one needs to be compared against real potatoes to understand what measured impacts could be actually causing damage.

SMARTSPUD PROVIDES QUALITY IMPROVEMENT INSIGHTS IN WA

By Georgia Thomas, Senior Project Manager, WA Potatoes

Following a successful application for funding to the Agriculture Produce Commission, Potato Producers Committee in 2020, the Potato Growers Association of WA (PGAWA) purchased a SmartSpud device for industry-wide use.

The SmartSpud is an electronic potato shaped device (pictured in a recent test) used to measure the damage caused by impacts potatoes receive during processing and transport to pinpoint and fix root causes. It does this by measuring the G-Force produced on the unit during harvest, sorting, washing or transport.

WA growers and packers are using the device to help discover where bruising, shatter damage and black spots might be occurring to assist increase potato quality and pack out.

The device was ordered from Masitek in Canada and arrived in late 2020. Upon receiving the device PGAWA staff undertook training in its use and how to interpret reports. The team then started practical training, testing the device on a wash packing line and then during harvest on-farm.

The initial trials highlighted the need for further fine tuning to troubleshoot a few issues. As such, staff have been liaising with Masitek to work through updates which are ongoing.

The trials also highlighted the wide-ranging use for the device and the opportunities for industry to make the most of the investment.

According to the manufacturers, the SmartSpud can reduce bruising and damage by up to 50%. Other benefits include:

Improve line efficiencies, targeting downtime and maintenance.

Test new equipment in quick time.

Measure levels of damage through all stages of processing.

Make data-driven decisions

Following initial testing and training a User Agreement was developed for WA potato industry members to access the device. The agreement

Figure 6. The SmartSpud consists of an accelerometer mounted inside a potato-shaped urethane capsule.

requiring members to undertake training so they can use the device effectively.

The device has already been used to investigate impact points in a wash packer process, and in August this year commenced on-farm testing of the harvest process.

David Anderson, Supply Manager for Beta Spud has been running the device in a range of settings and locations.

"We have had the opportunity to use the device from the outset and have so far been running trials across several farms and in our wash packing facility. The information we have

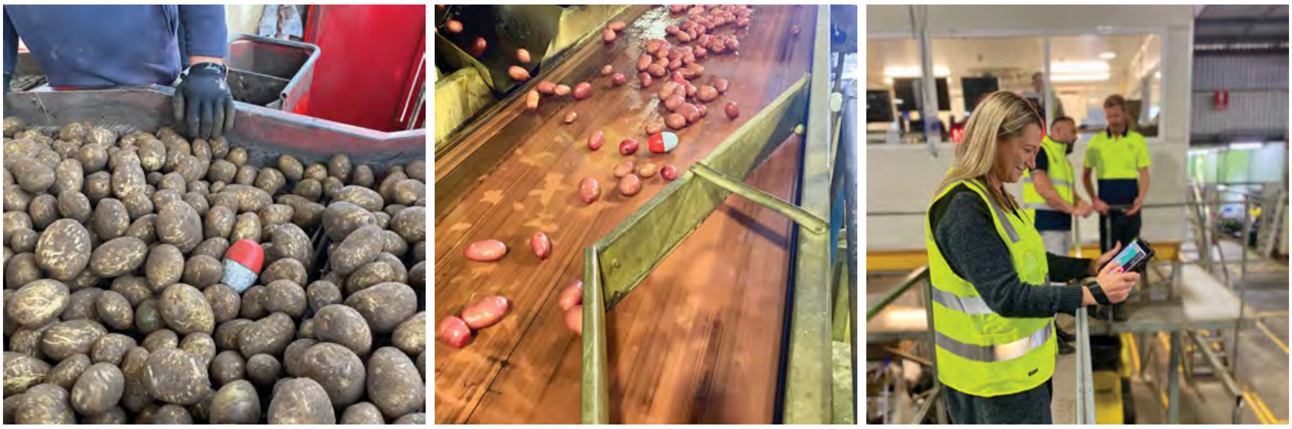


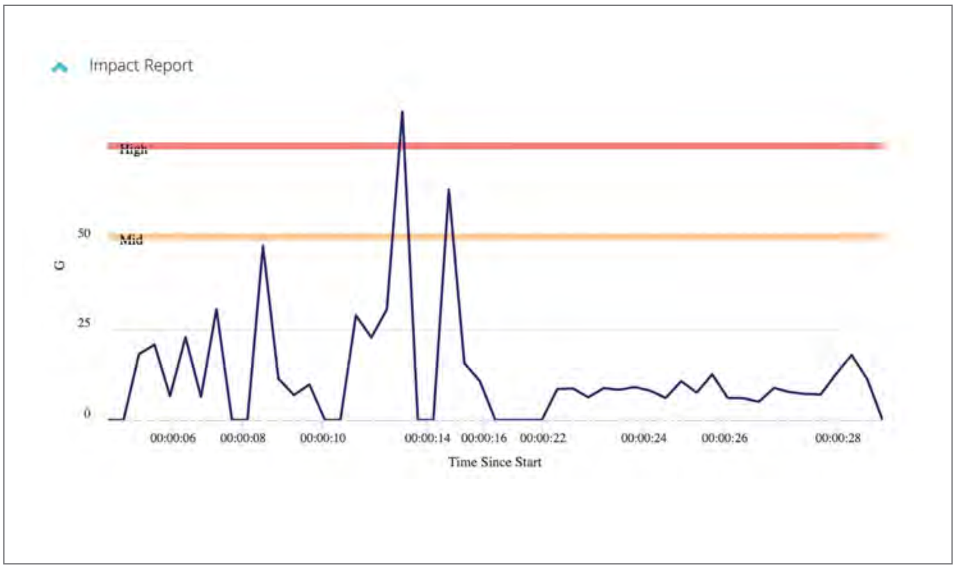
Figure 7. Initial testing of the SmartSpud on farm and at Beta Spud's packing facility, with progress monitored by Morena Perdec from PGAWA. All photos by Georgia Thomas, PGAWA.

gathered indicates that most areas on the harvester are within range. The SmartSpud has shown two minor areas that we can work on to improve quality within the packing shed," said David (Figure 7, Figure 8).

Moving forward, the PGAWA continues to support industry with training and use of the device with the goal of achieving incremental quality gains.

"As more growers take advantage of the device, more knowledge can be gathered about the specific areas of focus for industry. It is as much about ruling out issues and it is discovering where more effort should be focused to find improvements," said Potato Grower Association WA CEO Simon Moltoni.

Feedback from activities have continued to be communicated back to the manufacturer to enable improvements to be made to the device in future updates.



Read more about SmartSpud at aaggrrii.com/products/smartspud

Figure 8. Example of output from a SmartSpud. The two peaks indicate points in the packline where damage may be occurring.

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