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Monitoring Tools for a Potato Bruise Prevention Program

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Introduction

BRUISING OCCURS WHENEVER A POTATO impacts another surface, typically during windrowing, harvesting, conveying, and throughout the handling and packing process (Brook 1993; Hyde et al. 1992). Bruises are more prevalent after potatoes fall from a significant height; hit the metal sidewalls of a conveyor; experience abrupt changes in direction; and/or collide against insufficiently padded equipment. In conjunction with force, acceleration, drop height, and impact surface, the degree of bruise development depends on tuber characteristics such as cultivar and pulp temperature. Consequently, knowing a cultivar's response to a physical impact and the risk for bruise development are beneficial in developing a bruise prevention program.

Shatter and blackspot bruises are two main defects that influence potato quality (Figure 1). Both result from an impact by an external force and can occur on the same potato. Shatter bruise occurs when the external impact force is great enough to cause the cells to rupture by physically breaking the skin, where it forms cracks or cuts (Baritelle et al. 2000). Though the force may not

Figure 1. **A,** Potato tuber with shatter bruises. **B,** Blackspot bruises revealed after peeling a potato.

necessarily break the skin, if it damages the underlying cells a blackspot bruise will start to develop within a few hours. The black discoloration forms when the damaged cells' phenolic compounds (e.g., tyrosine) are oxidized by the enzyme polyphenol oxidase into a dark pigment called melanin.

Both bruise defects are serious, particularly when they cause direct and indirect losses. Losses may be from direct waste, customer rejections, weight loss, and decay due to disease. In 1993, a 10% reduction in bruise was estimated to return an additional 74.7 million dollars to the US potato industry (Brook 1996). Adjusting only for inflation, that same 10% improvement would be equivalent to 134 million dollars in 2020. Regardless, any improvement on quality significantly enhances the potato's economic value.

Given the economic consequences of potato bruising, it is critical to quickly identify shatter and blackspot bruises and to pinpoint where impact forces occur in an operation. This bulletin provides crucial tools and detection methods that will help make effective management decisions to minimize bruising and thus mitigate quality issues.

Shatter Bruise Monitoring

Shatter bruise appears as cuts or cracks in the skin that reduce the visual appeal to a consumer. Water loss through these wounds is greater until healed. These cracks and cuts are also entry points for diseases such as Pythium leak, bacterial soft rot, and Fusarium dry rot.

Monitoring shatter bruise levels during handling operations provides opportunities to modify equipment and conditions and to identify lots or fields that have a greater degree of shatter bruise. A high level of shatter bruise at harvest will demand more intensive storage management that promotes wound healing, minimizes disease development, and avoids higher weight loss and pressure flattening and bruise.

A relatively simple way to detect shatter bruises is to use an iodine solution. Iodine interacts with starch to form a blue color. Any break in the skin of the potato exposes the starch in the tissue to the

Iodine Staining Procedure

Preparation

- Identify various handling operations where bruising may be a problem (windrower, sharp directional changes, harvester, truck to stinger, etc.).
- Sample 15–25 potatoes from each location. Keep them separated in mesh bags. **Label the bags by location**. Mesh bags keep samples separated and make it easier to wash off soil and iodine from the potatoes.
- Procure the following supplies:
    - » Two containers large enough to fit multiple samples of 15–25 potatoes that are submerged in liquid
    - » Iodine solution (label will say "1% or 2% titratable iodine")
    - » Mesh bags to hold samples

Protocol

1. Wash tubers to remove excess soil. Washing potatoes will help keep the water clean and allow bruises to color more readily.
2. Prepare the containers. Fill both containers with enough water to submerge the potatoes in the mesh bags (use one to submerge the potatoes in iodine and the other to wash/rinse them after the iodine bath).
3. Mix the iodine solution (Table 1). Combine the iodine with water to produce a specific ratio, which determines the length of time the tubers need to soak to reveal any shatter bruises. For example, a 1:1 (volume of iodine solution to water) ratio requires at least 20 minutes for shatter bruises to turn color. A ratio of 1:15 will need at least 60 minutes. **Note**: if reusing the iodine solution, you may need to wait longer before potatoes discolor.

Figure 2. The wounds on these potatoes are dark blue or black from soaking in a dilute iodine solution.

iodine solution, which turns a blue or black color (Figure 2). This coloration makes it easy to determine the number and severity of the shatter bruises. Commercial iodine solutions (1%–2% titratable iodine) can be found at most farm/ranch stores in the livestock department. These solutions are considered safe and generally prevent infection of wounds on livestock. The procedure is simple but requires some initial setup.

Although the iodine staining procedure helps to identify the level of shatter bruise that occurs during handling operations, an absence of shatter bruises does not mean physical impacts are not damaging potatoes. The impact may be causing blackspot bruise instead.

Blackspot Bruise Monitoring

Blackspot bruise forms when the damaged cells' phenolic compounds are oxidized by the enzyme polyphenol oxidase, which in turn produces quinones (pink color), and then transforms into dark pigments (melanin). To check for bruising, the potato must be peeled. The damaged cells appear as pink, red, brown, or black spots. Development of the black pigment is not immediate, however; it takes time to become visually apparent. The darkening is irreversible and considered a defect both for fresh and processing potatoes. Ideally, the sooner blackspot bruises are identified from impacts caused by conditions or equipment, the easier it will be to implement more effective changes or adjustments to reduce the potential for blackspot bruising. Peeling potatoes to identify the proportion of early blackspot bruise symptoms is therefore a useful tool to prevent further damage and to adjust handling protocols for bruise control.

4. Soak potatoes in mesh bags for the appropriate time in the dilute iodine solution.
5. Wash or rinse potatoes in a second container filled with water.
6. Count the number of shatter bruises per tuber in each sample (potatoes do not need to be peeled to see the shatter bruises).
7. Wear gloves and dispose of the used iodine solution in the same manner as other pesticides.
8. If the iodine:water solution is fairly clean, simply cover, store, and reuse it. Solutions should not be kept for more than four days. However, the extremely dilute solutions (1:6.5 or less) will not keep for more than two days. Discard tubers after the evaluations are complete and do not allow them to enter the food system. **Note**: Efficacy of the iodine solution decreases the more it is used and if exposed to sunlight.

Table 1. Iodine to water ratios to test for shatter bruise.

Ratio (iodine:water)	Iodine solution (gal)	Water (gal)	Time for tubers to color (minutes)
1:15	0.6	9.4	60
1:6.5	1.3	8.7	50
1:3	2.5	7.5	30
1:1	5	5	20

Note: To make 10 gal of a diluted iodine solution, mix various ratios of iodine to water. The table describes the volumes of iodine solution (1% titratable iodine) and water to make up 10 gal. The time needed for coloration to occur is dependent upon the ratio. Total gallons of the mix can be adjusted based on size of containers and number of samples.

Early Blackspot Bruise–Monitoring Technique

This method allows early detection of bruise incidence but does not identify 100% of the bruises and scorable defects that will develop over a longer period of time.

1. Collect samples. Take tuber samples from multiple locations within the handling operation. Areas to consider: where tubers experience directional changes, drop from a conveyor, or move through specific pieces of equipment. Label the samples by location to keep track of the test areas.
   a. Sample size depends on the operation—if there are multiple opportunities for impact in the sampling area, take a larger sample. Each sample should range from 10 lb to 40 lb per location.
   b. Measure and record tuber pulp temperatures.
2. Hold tubers at warm temperatures.
   a. Place samples at room temperature (e.g., 70°F) for 3–5 hours. If it's necessary to test for the total incidence and severity of blackspot bruise, hold tubers for 24–48 hours before peeling.
   b. If you use a hot box (90°F–100°F), the duration of time until discoloration develops may be shorter but the severity of bruises may be slightly exaggerated at these higher temperatures.
3. Assess bruise.
   a. After tubers have been warmed for 3–5 hours, peel the skin and examine for discoloration.
   b. You may need to peel a few more layers of the potato to see the darkest discoloration.
   c. Discoloration will range from pink to dark brown the first few hours after impact (Figure 3). **Note**: Not all bruises will have formed at this time, especially mild bruises from lower impacts.
4. Examine all the peeled tubers and make note of the incidence and severity of the bruises.
5. Based on the level of bruising, make equipment adjustments to reduce impact forces at the sample location.

Figure 3. Range of bruise color seen within five hours in a Russet Burbank after an impact of 12 inches (30 cm) by a metal weight.

The early blackspot bruise monitoring technique was derived from a series of experiments utilizing multiple cultivars and years. The studies suggest discoloration, primarily pink discoloration, began to develop within the first hour after impact (Table 2). The change in bruise color from pink to brown primarily occurred 2–3 hours after impact, and pink discoloration declined rapidly after that time. The highest incidence and severity of blackspot bruise occurred at 24 hours; however, over 75% of the total bruises could generally be seen after 3–5 hours, depending upon force of impact and cultivar. For example, Russet Norkotah appeared slower while Ranger Russet was faster to develop blackspot bruises.

These studies highlight the utility of pink- or brown-/black-colored bruises as an early indicator of blackspot bruise incidence within an operation; but be aware that bruise development differs based on the cultivar. Also, lighter colors may indicate the freshest bruises, which can help in pinpointing the bruise source. Lastly, you can begin making bruise assessments within a few hours after sampling—it is not necessary to wait twenty-four hours. Use your monitoring results to modify equipment, operation management, and/or other conditions to minimize blackspot bruise potential.

Table 2. Blackspot bruise incidence (%) for three cultivars bruised at a twelve-inch drop height with pulp temperatures of 55°F and evaluated at room temperature (70°F).

Variety[1]	Bruise Coloration Index[2]	Hour Evaluated					
		1	2	3	4	5	24
		Blackspot Incidence (%)					
Russet Burbank	Pink	54	62	46	14	6	6
	Total	54	65	73	77	80	95
Russet Norkotah	Pink	29	43	36	21	7	2
	Total	29	46	52	64	67	88
Ranger Russet	Pink	58	29	7	6	2	0
	Total	70	74	76	82	79	97

[1]Russet Burbank and Russet Norkotah were examined twice in 2018 and once in 2019. Ranger Russet was only examined in 2019. Trials in multiple years were combined.

[2] Pink incidence only includes bruises that were rated a 2 on the blackspot bruise color intensity scale (1–5): 1 = none, 2 = pink, 3 = light brown, 4 = dark brown, 5 = black discoloration. Total incidence includes ratings of 2–5.

Instrumented Sphere

An instrumented sphere is a logging device that measures and records the acceleration of an impact whose data can indicate which equipment, locations, or areas may increase the risk for bruising (Figure 4). The most problematic locations are where drop heights are large, padding is worn, and/or belt speeds are too fast (Figure 5).

The data an instrumented sphere records includes

- Peak acceleration as g-force (1 g = 9.8 m/s2). This data is measured by accelerometers and indicates the magnitude of an impact.
- Change in velocity. This measurement accounts for the impact surface and magnitude of the impact. **However, not all instrumented sphere models record change in velocity**.
- A time stamp. This log identifies when the impact took place. It helps to determine the locations that recorded damaging peak accelerations when testing multiple potential points of impact.

Peak acceleration and change in velocity are used to estimate a bruise threshold—defined as the force required to bruise a certain percentage of potatoes from one impact. For example, when Mathew and Hyde (1997) studied the bruising of potatoes that had been dropped 1 inch above a steel surface, the 10% bruise threshold was reached; however, the bruise threshold increased to 10 inches when the steel was coated with a cushioned material. The more rigid a surface, the lower the change in velocity, which increases the likelihood of bruising. If change in velocity is not recorded, then the threshold relies on the maximum acceleration that will cause a bruise. **Note**: the data from an instrumented sphere manufactured by one company cannot necessarily be interchangeable with the data from another instrumented sphere due to potential differences in technology, weight, and size, which affect both the recorded impact and change in velocity.

An individual instrumented sphere may or may not come with a preprogrammed bruise threshold. In general, typical thresholds range from 40 g to 80 g but need to be determined for varying cultivars and operating systems. Cultivars may react differently to a given impact and have a higher or lower bruise threshold. Bruise threshold can also be affected by pulp temperature and impact material. An instrumented sphere can be calibrated to determine the appropriate bruise threshold by testing the amount of bruise that occurs for each cultivar at different drop heights and pulp temperatures. Quantifying the amount of shatter and blackspot bruise, as described previously, and corresponding it to data recorded by the instrumented sphere will help to fine-tune bruise thresholds.

Figure 4. Example of an instrumented sphere [Techmark Impact Recording device (IRD)] placed on top of the soil to be harvested with potatoes to monitor the impacts during harvest.

Figure 5. An IRD (red ball) recording impacts as potatoes are being conveyed in a fresh pack operation.

Conclusion

Monitoring tools such as the iodine solution, rapid bruise development, and/or the instrumented sphere provide targeted information regarding beneficial modifications to operations, equipment, and/or conditions. Having quick, reliable, and easy information that identifies where to make these changes will result in fewer quality defects and losses.

Protocol to Establish Bruise Thresholds

1. Drop potatoes from different heights onto various materials and record if blackspot and/or shatter bruise forms (pulp temperature should be noted as well). **Repeat for each cultivar**.
2. Drop an instrumented sphere at those same heights and onto different materials to obtain peak acceleration and change in velocity (if recorded).
3. Document the relationships that exist in the data.
   a. Plot the relationship between bruise incidence and drop height.
   b. Plot the relationship of peak acceleration and change in velocity (if available).
   c. Plot the relationship of drop height and peak acceleration.
4. Set an appropriate bruise threshold for an instrumented sphere.
   a. This may change based on impact surface, temperature, and cultivar.
   b. Use manufacturer information for guidance.
5. Run an instrumented sphere through each specific piece of handling equipment. Data is easier to interpret with 1 location of interest per run, but access to equipment may require multiple locations to be tested in each run (3 or less is ideal). Repeat runs at least 3–4 times to identify consistency in equipment. The results of the instrumented sphere may change from one run to the next as it falls onto potatoes, belts, or metal frames. Results consistently above the threshold indicate more potatoes are likely to bruise than when results vary or are below the identified threshold. However, adjustments may need to be made in both circumstances.
   a. **Note that an instrumented sphere sinks in water**. Do not place it in flumes or wash barrels.
   b. **It is important to have many observers watch an instrumented sphere because it can easily get lost**. Shorter runs make it easier to track.
6. Locations with peak accelerations above the set threshold have a high potential for causing bruises. Check data by quantifying the bruising from samples collected at locations having above-threshold impacts.

Equipment Modifications After Evaluations

Results from bruise monitoring assessments will dictate if further steps need to be taken to minimize shatter and blackspot bruises. Modifications may include adjusting or consulting the following:

7. Harvest/handling equipment
   a. lower drop heights
   b. add/replace cushioning
   c. run belts full of potatoes
   d. ensure proper equipment operation
8. Environmental conditions
   a. lower/raise tuber pulp temperatures
   b. ensure proper soil moisture

For additional information to bruise management, refer to https://www.uidaho.edu/cals/potatoes/bruise-management

After making adjustments to problem locations, resample to ensure the adjustments lowered the bruise level.

Further Reading

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Photo credit

Figure 5 courtesy of Carlos Centeno.

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