Potato Progress

Research & Extension for the Potato Industry of Idaho, Oregon, & Washington

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www.nwpotatoresearch.com

Volume XVI, Number 13 | *23 September 2016*

Be Aware of Lenticular Soft Rot and How to Minimize it in Potatoes

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Pit rot or lenticular soft rot is a disease typically caused by one or more species of soft rot bacteria (such as *Pectobacterium*). Pit rot lesions are small (usually 0.01 – 0.2 inches in diameter) round, dark sunken lesions centered on lenticels (Fig. 1). Neighboring lesions may coalesce to form larger, irregularly shaped sunken areas (Fig. 2). Pit rot differs from normal tuber soft rot in that the infection is limited to the lenticel and conditions are usually unsuitable for full soft rot development. Unfortunately, as packing sheds scramble to meet fresh market demands, we hear reports of problems with this disease almost annually at this time of year.

These bacteria can be found on contaminated tubers, plant debris, in field soil, wash water, or handling equipment. They often become problematic in the packing shed after tubers are washed and placed in large totes, plastic bags or boxes when still wet. Natural openings in the tuber called lenticels are excellent points of entry for the bacteria, particularly when the lenticels become enlarged due to lack of oxygen, such as when they are covered by a film of water after washing. A healthy tuber with access to ample oxygen can usually guard against invasion of these pathogens through the lenticels due to oxygen-dependent host resistance systems. However, when oxygen is depleted, such as when tubers are covered in a film of water after washing and then stored at ambient temperatures (above 60°F), they are oxygen-deprived and their defenses are compromised. As carbon dioxide levels rise, lenticels open further, and the resulting enlarged lenticels allow easier entry of the anaerobic bacteria, which can still infect in the absence of oxygen and reproduce rapidly. Just a thin film of water can promote disease in as little as 12 hours, meaning that tubers washed and allowed to sit in wet conditions overnight may develop pit rot by the next morning. Pit rot rarely leads to full-blown soft rot if tubers dry out and then are able to limit infection.

To minimize the risk of promoting lenticular soft rot in the packing shed for fresh-pack potatoes that are being shipped soon after harvest, we recommend the following:

- Measures should be taken prior to harvest to avoid the build-up of soft rot bacteria on the tuber surface. These include reducing irrigation and allowing tubers sufficient time after vine kill to set skin and not harvesting in muddy conditions, to reduce the amount of soil on the tuber surface.
- If soft rot is present at harvest, the tubers should be graded as they are washed and packed or moved into storage.
- When washing or transporting tubers in fluming systems, tubers should not be submerged in flumes or dump tanks any longer than absolutely necessary. Bacteria in the water will be absorbed through lenticels and any wounds.
- If fluming systems are used, the system should be cleaned and sanitized frequently.

- Clean, chlorinated water or water treated with an effective biocide should only be used for washing fresh-market potatoes on the packing line. Dirt in wash water will deactivate most biocides. Wash-water should not be re-circulated.
- After washing, tubers should be stored below 60°F and in well-ventilated conditions, even if they are only being stored for a short period of time before shipping. This practice will dry up water films on the tuber surface and prevent infection.

Of the above recommendations, observations at packaging houses in Idaho suggest that the most important thing a grower can do to limit pit rot is to ensure that tubers are stored below 60°F with good ventilation after washing. There are many other strategies that can be implemented before, during, and after harvest, as well as before and during storage, for tubers that will be stored before packing. You can find more information about managing lenticular sot rot online at the following sites:
http://cru.cahe.wsu.edu/CEPublications/FS066E/FS066E.pdf
http://pnwhandbooks.org/plantdisease/potato-solanum-tuberosum-bacterial-soft-rot-blackleg-and-lenticel-rot

Figure 1. Tuber lenticel or pit rot.

Figure 2. Lenticel rot showing coalescence of lesions.

New Potato Varieties from the Western Region Show Promising Consumer Attributes During Long-term Storage

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With the declining of Russet Burbank acreage, demand of new potato varieties for the frozen fry processing industry is increasing. New varieties need to show not only premium agronomic quality, like yield, size profile, and specific gravity, but also good long-term storability with low reducing sugar, long dormancy, low disease incidence, low weight-loss, etc. They should also make nice colored French fries with white fluffy interior and crispy external for the QSR (quick service restaurants) customers. Therefore consumer attributes, particularly fry texture is of great importance when assessing a new variety's commercial potential. The unsuccessful adoption of Premier Russet a couple of year ago drew the attention of the potato researchers to evaluating consumer attributes before considering release of new varieties.

The longtime variety storage study conducted at University of Idaho Kimberly Potato Storage Research Facility has evaluated dozens of new promising varieties over the last 18 years. Many of those varieties has been named and released to the processing industry, such as Classic Russet, Clearwater Russet, Payette Russet, Teton Russet, etc. Previously this study has focused on sugar content, weight loss, dormancy length, and dry rot disease development during long-term storage. Recently, testing of consumer attributes was added.

The consumer attribute test includes assessment of color variation and sugar end severity, as well as internal and external texture of the finished fries. According to industry standards: color variation is defined as at least one shade darker or lighter than primary color of the entire fry when comparing to the USDA French fry color chart; sugar end is defined as dark ends with #3 USDA color at least 0.64 cm in length on at least two sides of the finished fry. Internal texture evaluation includes four categories: good fluffy appearance (Fig. 1), limp units – meaning the fries don't break open and bend like rubber bands (Fig. 2), wet texture (Fig. 3), and hollowed interior (Fig. 4). External texture evaluation is to roll the fries between panelists' fingers and thumb, and feel for the corners and edges of the fries. A good unit is defined as one that all four edges can be felt on at least 2/3 of the fry.

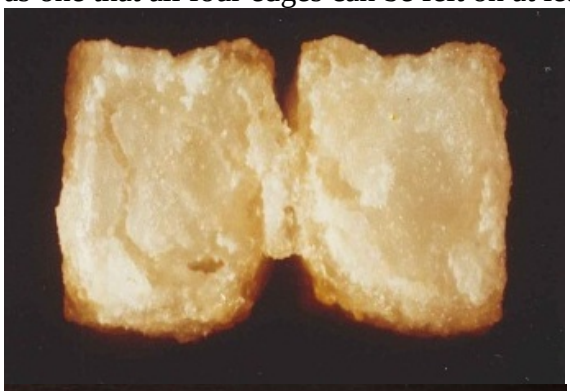

Fig. 1 Good fluffy internal texture.

Fig. 2 Limp Unit.

Fig. 3 Wet texture.

Fig. 4 Hollowed interior.

Materials and Methods

Six new promising varieties were planted, grown, harvested, and stored in University of Idaho Kimberly R&E Center in the 2015-16 season. Those varieties include: A03921-2, A06021-1T, Canela Russet, Echo Russet (AO96141-3), Mountain Gem Russet, and standard check Russet Burbank. Irrigation, fertilization, pesticide, and herbicide management strategies were based on best management practices recommended by University of Idaho extension personnel. After harvest in late September, potato tubers were wound healed for two weeks at 12.8°C and then storage temperature was ramped down to 5.6, 7.2, and 8.9°C for remaining storage season. Sprout inhibitor CIPC was applied in late November. After four and eight months in storage, potato tubers under all three temperatures were taken to University of Idaho Caldwell Food Technology Center for processing frozen fries, using the industry standards with minor modifications as shown below:

- Steam peel the tubers at 100 psi for 45 sec, and then transfer to Hobart Abrasion Peeler to run for 20 sec;
- Cut tubers into strips with industrial French fry cutter (0.71 cm × 0.71 cm), and rinse with cold water until the next step;
- Heat water to 85-88°C, and blanch strips at 79-85°C for 5 min;
- Dip the blanched strips in 0.5% (w/w) Sodium Acid Pyrophosphate for 30 sec at 71-74°C;
- Oven dry the strips at 73-93°C until weight reduction of about 15% is reached;
- Partially fry the strips at 188-191°C for 45 sec, drain and cool for no longer than 3 min;
- Quick freeze the strips at -20°C for 1 min, stir, and allow to freeze for at least 30 min;
- Bag the strips into coolers with dry ice and take them back to the Kimberly lab, freeze store them under -20°C until finished fry processing.

On the day of finished fry processing, 50 frozen strips of each replication (3 replications from each variety/storage temperature/storage duration treatment) were fried at 177°C for 2 min and 45 sec and quickly placed under heat lamps. Only strips that are longer than 5 cm were used for evaluation. Color

variation, sugar end severity, and internal texture of the strips were evaluated under the heat lamp within the first 6 min after they were fried, and external texture were assessed under the heat lamp after 7 min out of the frying oil.

Results and Discussion

Table 1 shows the ANOVA results of the treatment effects on consumer attributes of the new varieties during long-term storage. It is noticed that varietal effect, or in other words the genotypic factor, is always significant in influencing all of the consumer attribute parameters measured in this study. Storage duration (4 vs. 8 months post harvest) only significantly affects the incidence of poor internal texture, i.e. limp unit, wet texture, and hollowed interior, and storage temperature merely has impact on color variation of the French fries. For treatment interaction effects, only color variation, wet and hollowed interior is significantly affected by storage duration and storage temperature interaction; and the three-way interaction between the three treatments is significant just on incidence of color variation and fluffy internal texture.

Table 1. ANOVA table for effects of storage duration, variety, storage temperature, and their interactions on consumer attributes of the new varieties during long-term storage.

Source of variance	***Color variation***	***Sugar End***	***Internal texture***				***External texture***
			Fluffy	*Limp*	*Wet*	*Hollow*	*Good External*
Storage Duration (D)	0.541	0.071	0.319	0.01**	0.007**	0.017*	0.112
Variety (V)	<0.001***	<0.001***	0.009**	<0.001***	0.013*	<0.001***	0.009**
Storage Temp (T)	<0.001***	0.897	0.129	0.059	0.617	0.906	0.836
V*T	0.116	0.820	0.290	0.690	0.572	0.551	0.827
V*D	0.068	0.755	0.454	0.657	0.138	0.253	0.228
D*T	0.036*	0.907	0.083	0.347	0.018*	0.035*	0.416
V*D*T	0.005**	0.207	0.029*	0.100	0.119	0.632	0.368

*<0.05; **<0.01; ***<0.001

Regarding varietal difference, A03921-2 ranks the best in most of the tested consumer attributes: it showed the lowest color variation and sugar end incidence on the French fries, it had good fluffy internal texture and good external texture, and its incidence of limp unit and wet interior was among the lowest (Table 2). Echo Russet showed moderate color variation, and had fluffy interior and good external of the French fries, but its sugar end incidence was the highest, and it displayed higher incidence of wet and hollowed internal texture (Table 2). Canela Russet and A06021-1T ranked moderately in most of the tested consumer attributes, except that color variation of A06021-1T French fries was among the highest (Table 2). Mountain Gem Russet, which tends to be considered as a fresh table stock variety, showed lower incidence of fluffy internal texture and good external texture than most of the other varieties, and had higher incidence of color variation and limp unit (Table 2). Performance of Russet Burbank, as a standard check variety in this study, was similar to that of Mountain Gem Russet, with the exception that its color variation incidence is lower (Table 2).

Table 2. Incidence (%) of each consumer attribute among the 50 sampled fries from each variety across storage duration and temperatures. In each column, values followed by the same letter are not significantly different at α=0.05.

Variety list	***Color variation***	***Sugar End***	***Interior***				***External***
			Mealy	*Limp*	*Wet*	*Hollow*	*Good External*
A03921-2	12 c	2 b	77 a	10 d	5 b	4 b	90 a
Echo Russet	15 bc	15 a	74 ab	12 cd	10 a	8 a	89 ab
Canela Russet	22 b	1 b	73 ab	15 c	4 b	3 bc	88 ab
A06021-1T	48 a	2 b	73 ab	16 bc	5 b	4 b	88 ab
Mountain Gem Russet	40 a	1 b	67 c	24 a	5 b	2 c	83 c
Russet Burbank	20 b	7 b	63 c	21 ab	6 b	2 c	85 bc

Higher storage temperature at 8.9°C was associated with less color variation on the French fries both in mid and late storage season, averaged across varieties (Table 3). Lower storage temperature at 5.6°C after 4 months of storage resulted in the highest color variation over all varieties (Table 3).

Table 3. Effects of storage duration by storage temperature interaction on color variation of the French fries across varieties. Values followed by the same letter are not significantly different at α=0.05.

Storage duration	***Storage temperature (°C)***	***Color variation incidence (%)***
4 months post harvest	*5.6*	51 a
	7.2	23 b
	8.9	11 c
8 months post harvest	*5.6*	32 b
	7.2	25 b
	8.9	14 c

Over storage temperatures and varieties, there were significant differences between 4 and 8 months storage duration with regards to poor internal texture incidence: longer storage duration tends to result in more limp units, and less wet and hollowed internal texture (Table 4).

Table 4. Effects of storage duration on incidence (%) of poor internal texture across varieties and storage temperatures. In each column, values followed by the same letter are not significantly different at α=0.05.

Storage duration	***Limp unit***	***Wet texture***	***Hollowed interior***
4 months post harvest	13 b	8 a	5 a
8 months post harvest	20 a	3 b	2 b

Due to the significant three-way interaction, Fig. 5 shows the value of color variation incidence on the French fries from every variety by storage temperature by storage duration treatment. It is obvious that A03921-2, as the best variety in overall fry color, displayed low mean values (≤20%, Fig. 5) under all three storage temperatures at both sampling time points. In comparison, A06021-1T and Mountain Gem Russet, which did poorly in overall fry color variation (Table 2), showed relatively high mean values (>75%) under 5.6°C after 4 months of storage (Fig. 5). A06021-1T also showed relatively high mean value (>75%) under 7.2°C after 8 months of storage (Fig. 5).

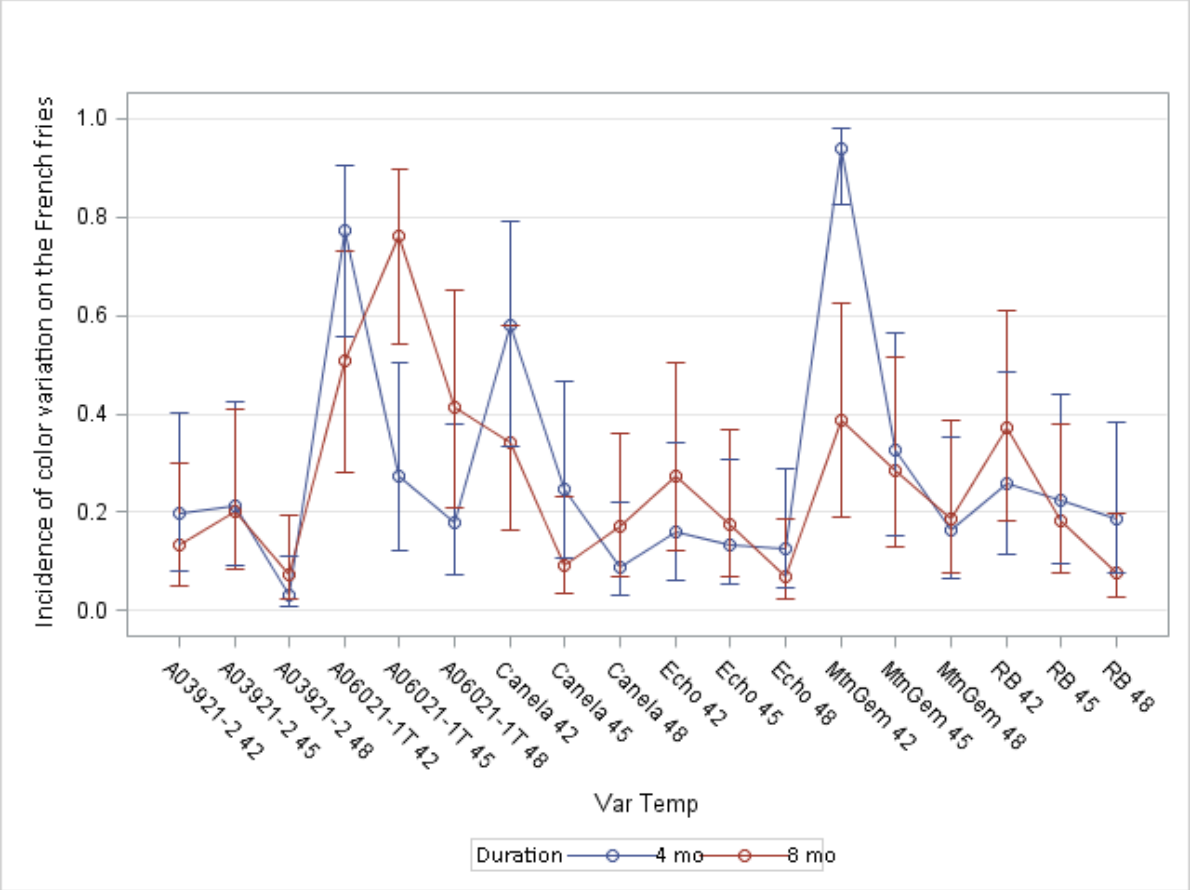

Fig. 5 Incidence of color variation of French fries from each variety/temperature/duration.

Due to the significant three-way interaction, Fig. 6 displays the incidence of good fluffy internal texture of French fries from each variety/storage temperature/duration treatment. Mean values of A03921-2 under all three storage temperatures after 8 months of storage are consistently higher than those of Mountain Gem Russet and Russet Burbank (Fig. 6). Mean values of Echo Russet under 5.6 and 8.9°C after 8 months of storage are also higher than those of Mountain Gem Russet and Russet Burbank (Fig. 6). A06021-1T at 5.6°C after 8 months of storage has a mean value higher than 80%, and Canela Russet at 8.9°C after 4 months of storage also has a mean value higher than 80% (Fig. 6). In comparison, Russet Burbank never has a mean value higher than 80%, across storage duration and temperatures (Fig. 6).

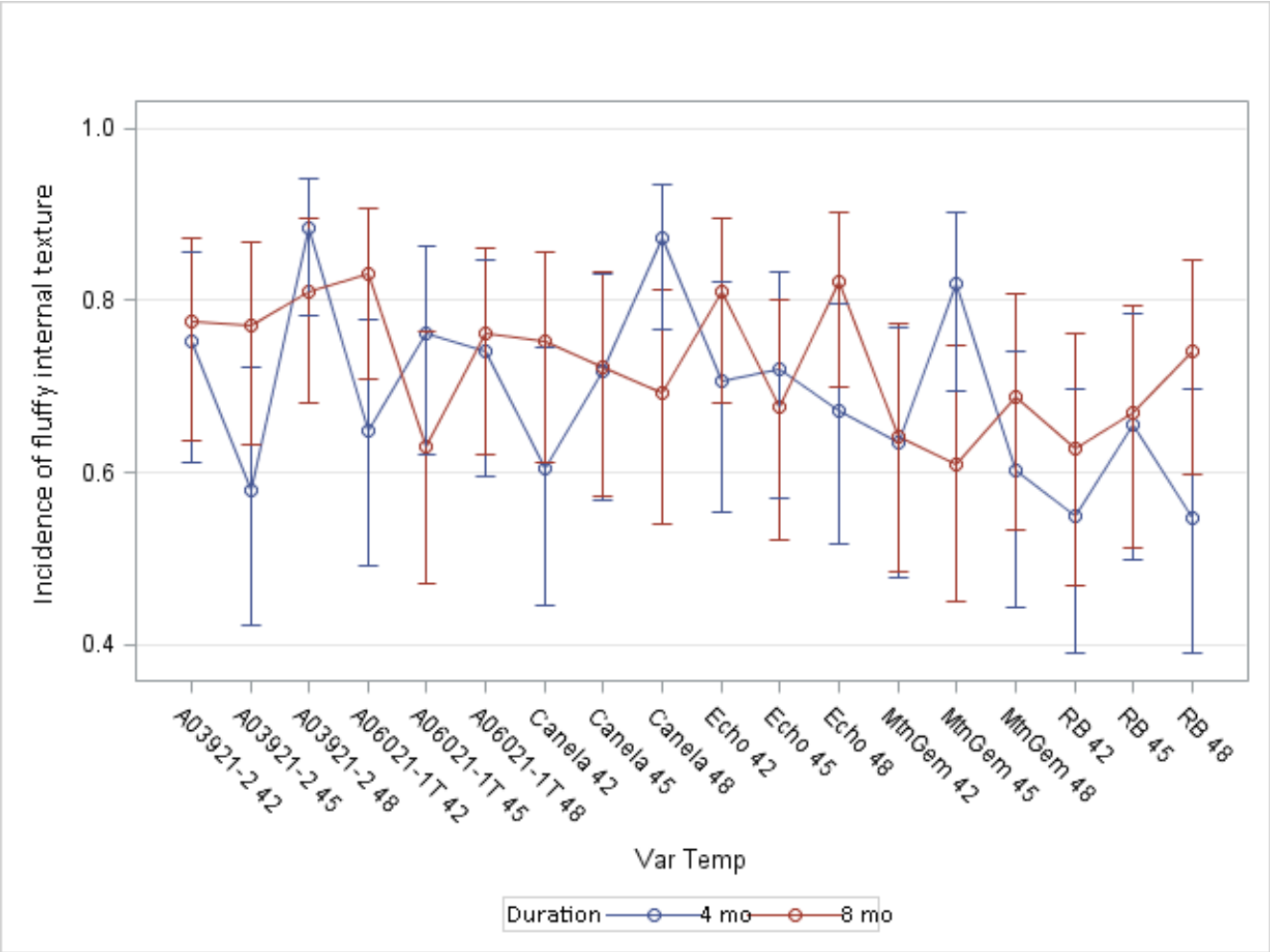

Fig. 6 Incidence of French fries with fluffy internal texture from each variety/temperature/sampling time treatment.

In summary, consumer attribute test during potato long-term storage can provide useful information about the processing quality of new promising varieties, which is important when evaluating their commercial potential and possibility of future adoption by the QSR. The test can find a potentially outstanding variety like A03921-2 that has performed well in all of the tested parameters, compared with Russet Burbank. The test might also identify some potential issues with the new varieties, e.g. the color variation of A06021-1T and poor internal texture incidence of Echo Russet, based on one year of data. Variety selection for the Kimberly variety storage study has been based on years of field trials, meaning that the varieties have already displayed premium yield and quality potential, and therefore consumer attribute test during storage will be a good addition to provide comprehensive overview for new variety development and future Russet Burbank replacement. Low storage temperature at 5.6°C and long storage duration for 8 months may have some impacts on degrading the fry color and internal texture for the French fries, and thus more research needs to be done in this area in the future.

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