Storage Management and Processing Quality of Umatilla Russet Potatoes

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Introduction

Umatilla Russet is a relatively new cultivar that was released from the Pacific Northwest Tri-State Potato Variety Development Program in 1998. While Umatilla tubers are similar to Ranger Russet tubers in appearance and resistance to internal defects, they lack the blackspot bruise problem that sometimes plagues Ranger Russet (Araji and Love, 2001). Like Ranger, Umatilla produces about 25% higher yield of U.S. No. 1 tubers than Russet Burbank. It has high gravity and good processing quality characteristics, making it ideal for the frozen French fry industry for which it was developed. The acreage devoted to Umatilla in Washington increased from 6.7% in 1999 to 12.3% in 2001 (Jensen, 2001). Umatilla tubers can maintain quality in storage longer than Ranger, but not as long as Russet Burbank. Potatoes for processing can be stored for up to 8 months. As with any new cultivar however, the increased adoption of Umatilla on a commercial scale has revealed some degree of variation in storability and processing quality in certain situations, underscoring a need for additional characterization of the storage biology of this cultivar.

This study was initiated in response to requests from growers and industry for further research on the postharvest behavior of Umatilla Russet, in relation to changes in processing quality over time. The following storage management questions were addressed during the 2000/01 storage season:

- Storage temperature – how low can we go without affecting a reduction in processing quality?
- Are there combinations or sequences of storage temperatures that interact to affect longevity and tuber quality?
- Can tubers that have undergone low-temperature sweetening be reconditioned at a higher temperature to improve their processing quality at the end of a storage cycle?

It must be emphasized that most of the results presented in this report represent one year of data spanning the 2000/01 storage season. Additional studies are currently in progress.

Materials and Methods

A 'temperature grid' protocol was used to assess the response of tubers to different storage temperature regimes. This approach is ideally suited to revealing how various temperatures, imposed at different times during storage, interact to affect longevity and tuber processing quality. Umatilla Russet tubers were harvested from a commercial field in the Columbia Basin on September 19, 2000 and placed in a commercial storage at 53^{o}F to wound heal (Fig. 1). The tubers were treated with 16.6 ppm CIPC on October 30, 2000 in the commercial storage. Samples of the sprout-nipped tubers were collected from the commercial storage on November 14, reducing sugars were measured, and the tubers were placed in 40, 44 and 48^{o}F storages at the potato postharvest research facility at Washington State University. The tubers remained at these initial 'conditioning temperatures' for 28 days. Samples of tuber tissue were again taken for determination of reducing sugars and fry color on Dec 12, whereupon tubers from each of the conditioning

temperature storages were transferred to 40, 44 and 48°F holding temperatures, where they remained for an additional 98 days. The tubers were sampled for reducing sugar and fry color analysis on Jan 16 and March 20, 2001. The study thus consisted of 3 conditioning temperatures factorially arranged with 3 holding temperatures for a total of 9 treatments (conditioning temperature x holding temperature combinations) (Fig. 1). To assess reconditioning potential, all tubers were placed at 60°F on March 20, where they remained until April 16, 2001. Hence, in addition to the initial 56 days in commercial storage, the experimental storage duration was 126 days plus 27 days of reconditioning for a total of 153 days. Reducing sugars and fry colors were assessed at the end of the reconditioning period.

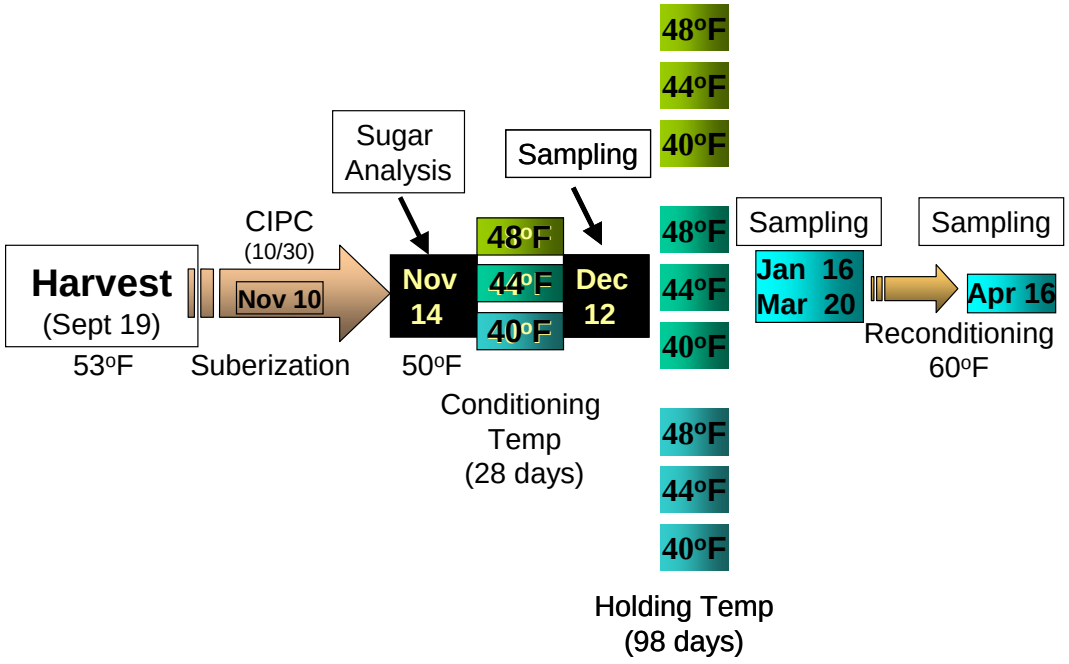


Fig. 1. Postharvest handling and storage protocol for Umatilla Russet tubers during the 2000/01 storage season. Tubers were held in a commercial storage until Nov. 14, 2000. Tuber samples were then placed at 40, 44 and 48°F (conditioning temp) for 28 days. Tubers from each of the conditioning temperatures were distributed to 40, 44 and 48°F for the main storage period. Tubers were then reconditioned at 60°F for 27 days. See text for further explanation.

French fries were prepared as described in Thornton et al. (2002) and fry colors were evaluated with a Photovolt reflectance meter. The reducing sugar concentration of tubers was inversely related to the lightness of French fries measured in reflectance units (Fig. 2). Figure 2 also shows the USDA color classes that correspond to the various ranges of Photovolt reflectance units. Lighter French fries have lower sugar concentrations, higher Photovolt reflectance values and lower USDA color ratings, reflecting a highly acceptable processed product. On the other hand, French fries with Photovolt readings of 19 or less (USDA≥3) are unacceptably dark.

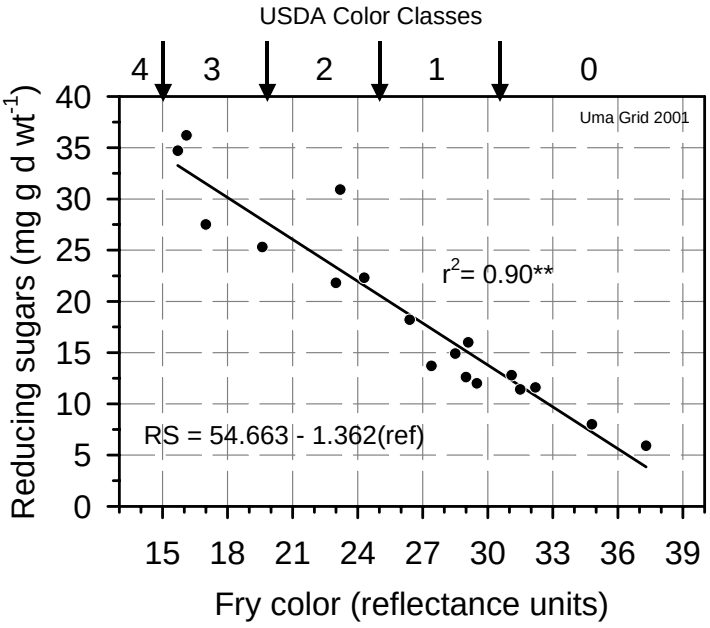


Fig. 2. Relationship between French fry color and tuber reducing sugar concentration (dry wt basis). Fry color was measured with a Photovolt reflectance meter. High reflectance units indicate light colored fries. The USDA color classes that correspond to specific ranges of reflectance units are indicated above the graph.

Results and Discussion

Response to Storage at Constant Temperature. The extent of buildup in reducing sugars in tubers over the 126-day storage period depended on temperature (Fig. 3). Reducing sugar concentrations increased 2-fold at 48°F, 4.7-fold at 44°F and 6-fold at 40°F through the 126-day study interval. Note that at any storage temperature, the greatest increase in reducing sugar concentration occurred during the initial 28-day conditioning period, suggesting that Umatilla tubers are most sensitive to low-temperature sweetening during the first several months of storage (tubers were harvested on Sept. 19). Comparisons of reducing sugar concentrations in Fig. 3 with Photovolt values and associated USDA color classes of French fries in Fig. 2 shows that tubers maintained excellent processing quality when stored at 48°F. In contrast, the processing quality of tubers stored for 126 days at 44 and 40°F had deteriorated to the point of being marginal and unacceptable, respectively.

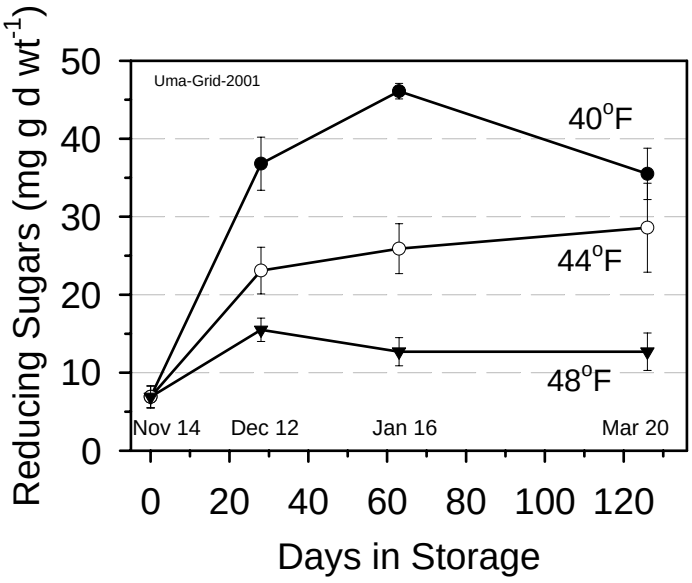


Fig. 3. Effects of storage temperature on the buildup in reducing sugars in Umatilla Russet tubers during the 2000/01 storage season. Tubers were harvested on Sept. 19 and held at 50-53°F until Nov. 14. CIPC was applied on Nov. 12.

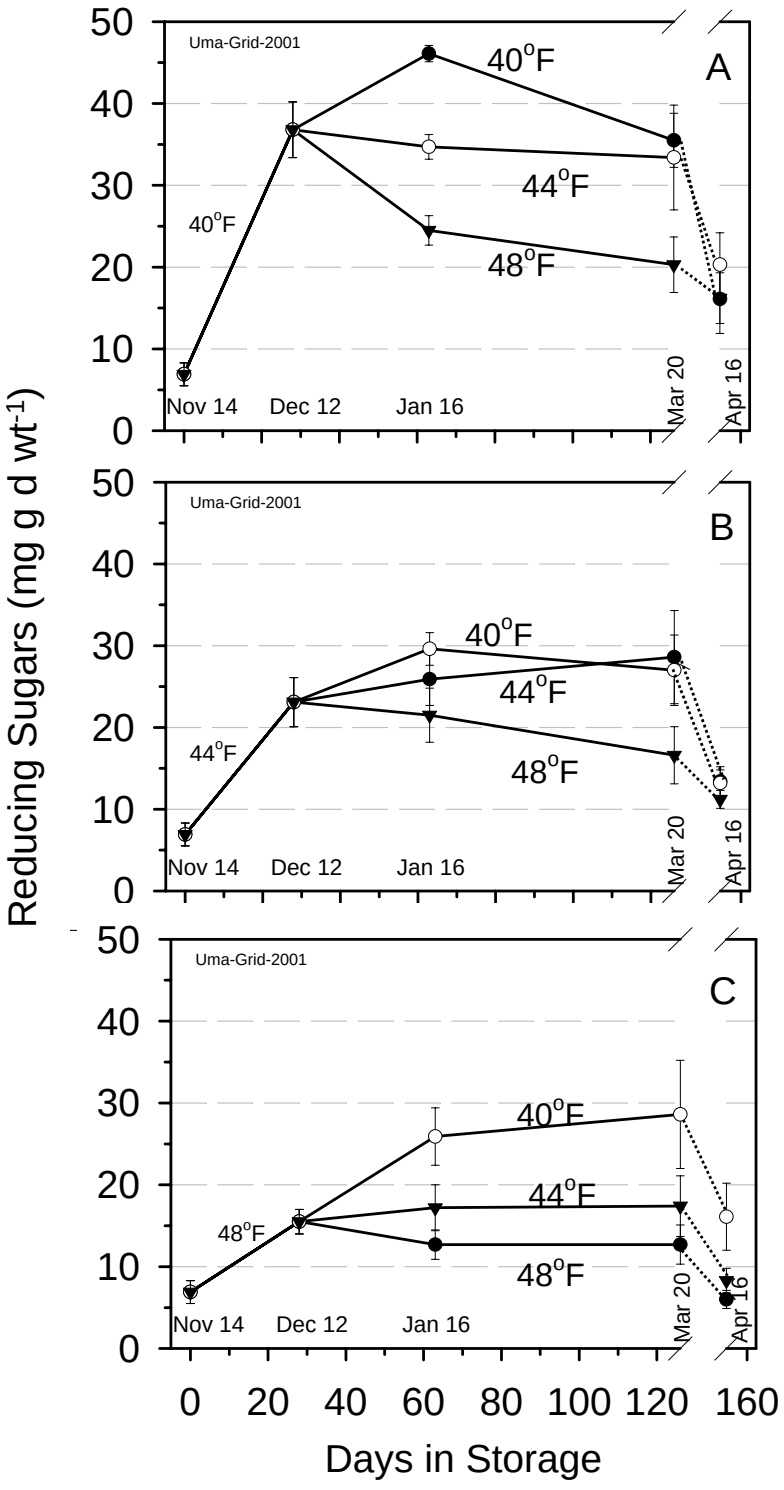


Fig. 4. Effects of 40°F (A), 44°F (B) and 48°F (C) conditioning temperatures (Nov. 14 to Dec 12) on the sweetening response of Umatilla Russet tubers stored subsequently at 40, 44 and 48°F for 98 days (Dec. 12 to March 20). Tubers were reconditioned at 60°F for 27 days (March 20 to April 16) at the end of the study.

Effects of Sequential Conditioning and Holding Temperatures. Conditioning temperature had a significant affect on reducing sugar concentrations early in the storage season. In general, the rate of sweetening over the 28-day conditioning period (Nov 14 to Dec 12) increased with decreasing temperature (Fig. 4ABC). At 40°F, reducing sugars increased 0.5% (dry wt basis) every 5 days over the 28-day conditioning period (Fig. 4A). In contrast, 9 and 16 days of storage at 44 and 48°F, respectively, were required to effect the same 0.5% increase in sugars over this period. (Fig. 4BC). Processing quality of French fries following the conditioning period was unacceptable at 40°F, marginally acceptable at 44°F, and acceptable at 48°F.

Tubers were stored at 40, 44 and 48°F for an additional 98 days after the conditioning period (Dec. 12 to March 20) (Fig. 4). Conditioning temperature interacted with subsequent holding temperature to affect the sweetening response in tubers over the 126-day storage period. Sugar levels in 40°F-conditioned tubers (Fig. 4A) declined significantly when stored subsequently at 48°F, reflecting partial reconditioning. No such reconditioning was apparent in tubers stored at 44°F however. Reducing sugars leveled off at an unacceptably high level when stored at 40°F over the 98-day holding period.

Interestingly, sugar levels in 44°F-conditioned tubers did not continue to increase when stored subsequently at 40 or 44°F for the remaining 98 days (Fig. 4B). This further indicates that Umatilla is most sensitive to low temperature sweetening early in the storage season. A similar response was evident for 48°F-conditioned tubers that were subsequently placed at 44°F for the 98-day holding period (Fig. 4C). However, tubers continued to sweeten if held at 40°F after a 48°F-conditioning period, although the final sugar level after 126 days of storage was significantly lower than that in tubers stored the entire period at 40°F (compare Figs. 4A & 4C). These data indicate that there may be potential in using lower temperatures later in the storage season to manage postharvest quality and longevity of Umatilla Russet, without inducing appreciable sweetening.

In a separate study, the increased sensitivity of Umatilla tubers to low temperature sweetening early in the storage season was shown to be due to relatively high levels of sucrose in the tubers at harvest (Fig. 5A). Regardless of whether tubers were stored at 44 or 48°F, sucrose concentrations fell at a constant rate over the initial 146 days of storage (Fig. 5A). However, during this period, reducing sugars increased 105% in tubers stored at 44°F, as compared with only 23% increase in those stored at 48°F (Fig. 5B). We speculate that the loss of sucrose at 48°F was likely due to higher rates of respiration

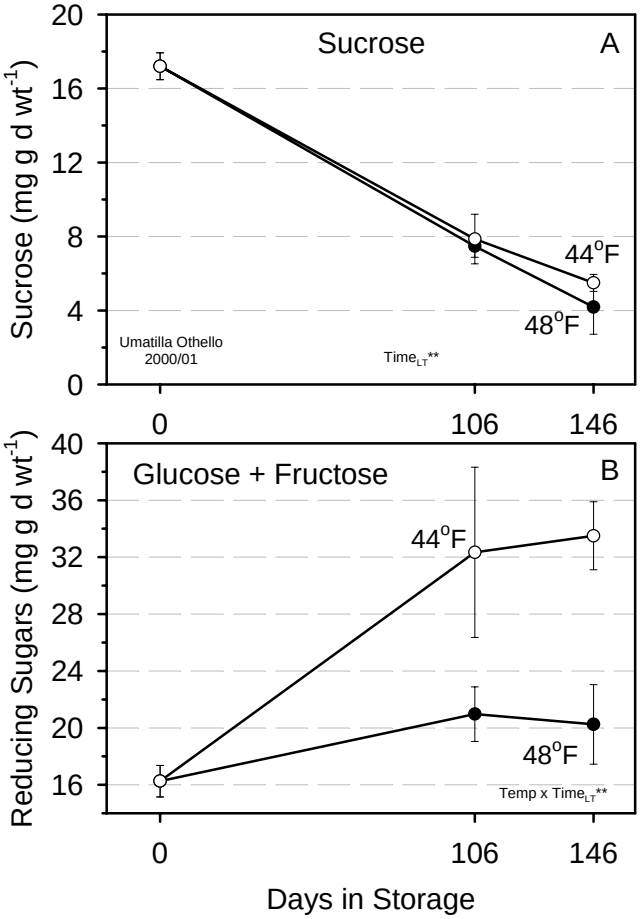
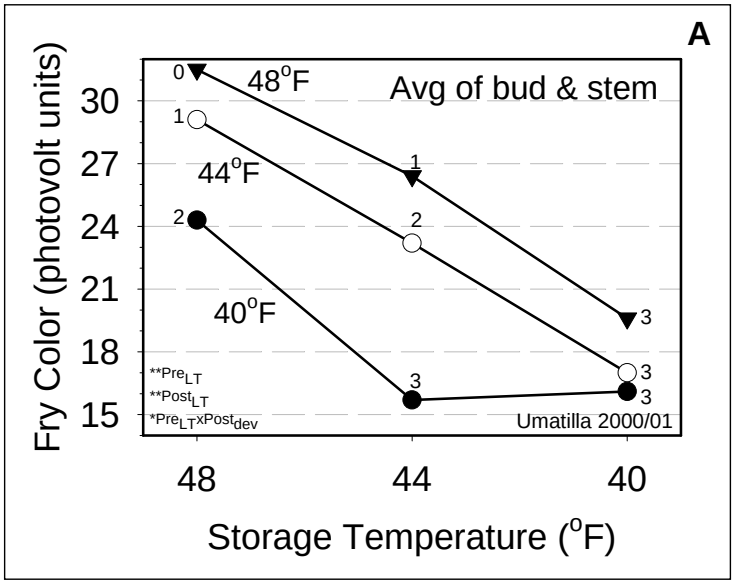


Fig. 5. Effects of storage temperature on changes in sucrose (A) and reducing sugars (B) in Umatilla Russet tubers as affected by storage temperature. Tubers were harvested Oct. 4, 2000 and stored at 44 and 48°F for 146 days. Note that at 44°F, sucrose was converted into glucose and fructose.

and starch synthesis, resulting in minimal reducing sugar buildup. On the other hand, 44°F was cold enough to stimulate hydrolysis of the sucrose to glucose and fructose, which thus accumulated in the tubers (Fig. 5B). Sucrose levels may thus provide a good indicator for more effective management of storage temperatures to maintain quality of this cultivar. For example, when sucrose levels fall below a critical level, Umatilla Russet tubers may tolerate colder temperatures. This may account for the reduced sensitivity of tubers to low temperature sweetening later in the storage season (Fig. 4BC). We are currently investigating this possibility.

The overall effects of conditioning and holding temperatures on French fry color at the end of the 126-day storage period are summarized in Figure 6. On average, Photovolt reflectance units fell with decreasing storage temperature, indicating a significant deterioration in processing quality (Fig. 6A). Tubers held at 48°F during the initial 28-day conditioning period produced lighter colored fries than those conditioned at 44°F, regardless of subsequent holding temperature. However, fries were unacceptably dark (USDA 3) when stored at 40°F for 98 days, regardless of the initial conditioning temperature (Fig. 6AB). Holding tubers at 40°F for 28 days initially in the storage season resulted in marginally acceptable fry color (USDA 2) if the tubers were stored subsequently at 48°F. Storage of the 40°F-conditioned tubers at 44 or 40°F produced unacceptably dark French fries (USDA 3) (Fig. 6AB).



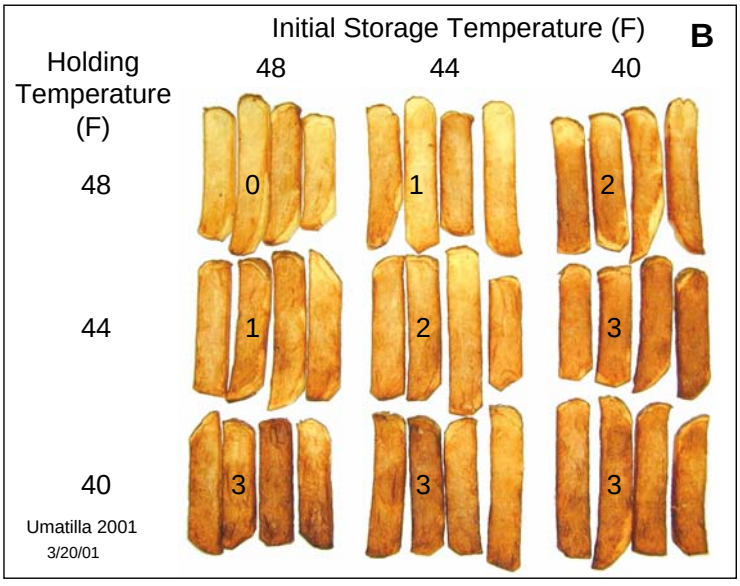


Fig. 6. (A) Changes in Umatilla Russet French fry color (Photovolt units) as affected by conditioning and storage temperatures. Tubers were harvested on Sept. 19, 2000, stored at 50 to 53°F until Nov. 14, conditioned at 40, 44 and 48°F for 28 days from Nov. 14 to Dec. 12, and stored for an additional 98 days at 40, 44 and 48°F (as labeled on the x-axis). Fries were processed on March 20, 2001. Numbers on each point indicate the USDA fry color rating. (B) Photo of French fries processed (March 20) from the tubers stored under the nine conditioning (initial storage temperature) and storage (holding) temperature combinations. USDA color ratings are shown on the fries from each treatment.

Reconditioning Ability. The extent to which reducing sugar concentrations can be lowered to restore processing quality through reconditioning was determined at the end of the 98-day holding period. Tubers were reconditioned at 60°F for 27 days from March 20 to April 16 (Fig. 4). Reconditioning affected a significant decrease in reducing sugar concentrations in tubers stored at all nine conditioning/holding temperature combinations (Fig. 4ABC). The greatest decreases were observed in tubers that had accumulated the highest levels of sugars in response to lower holding temperatures. Figure 7A shows the effects of decreasing storage temperature on reducing sugar concentrations in tubers at the end of the 126-day storage interval, with and without reconditioning. On average, reducing sugar concentration doubled in tubers as storage temperature declined from 48 to 40°F (Fig. 7A) and this resulted in a proportional decline in French fry processing quality (Fig. 7B). However, reconditioning significantly reduced tuber reducing sugar concentrations by 32%, 47% and 50% in tubers stored at 48, 44 and 40°F,

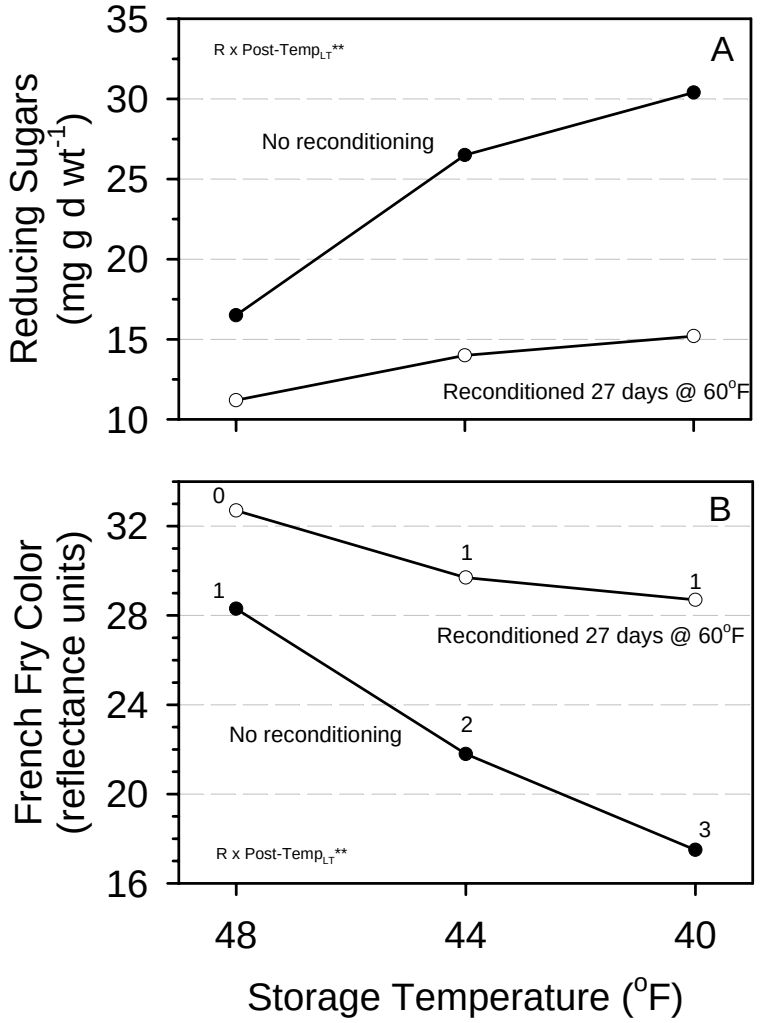


Fig. 7. Effects of storage temperature and reconditioning on reducing sugar concentrations (A) and French fry colors (B) of Umatilla Russet tubers. Tubers were harvested on Sept. 19, 2000 and stored until March 20, 2001, as described in Fig. 4 (data is averaged over the initial conditioning temperatures). Reducing sugars and French fry colors were assessed at the end of storage on March 20, 2001 and after reconditioning at 60°F for 27 days (March 20 to April 16). Numbers on each point in the lower graph indicate the USDA fry color ratings.

respectively (Fig. 7A), resulting in restoration of French fry processing quality (Fig. 7B). Tubers stored at 48°F produced USDA-1 fries that improved to USDA-0 in response to reconditioning. Tubers stored at 44°F produced USDA-2 fries that improved to USDA-1 in response to reconditioning. The greatest reconditioning response was observed in tubers stored at 40°F, where fry color changed from an unacceptable USDA-3 to an acceptable USDA-1 rating. These data clearly show that cold-sweetened Umatilla Russet tubers can be successfully reconditioned to improve French fry processing quality.

Summary and Conclusions

- Umatilla Russet tubers were the most sensitive to low temperature-induced sweetening (reducing sugar buildup) during the first three to four months following harvest, when sucrose levels were relatively high. Temperatures below 48°F should be avoided during this critical period.
- Storage at 44°F too early (e.g. within the first 80 days after harvest) can stimulate reducing sugar buildup that may lead to reduced processing quality later in the season.
- Storage at higher temperatures early in the season (e.g. 53°F after harvest gradually lowering to no less than 48°F over a 3-month period) will limit the ultimate reducing sugar accumulation at any subsequent holding temperature (e.g. 40 and 44°F) later in the storage season. This will permit the use of lower temperatures (e.g. 44°F) later in the storage season, which would likely be advantageous to the postharvest life and quality of this cultivar.
- Tuber sucrose levels may provide an indication of when, and to what extent, storage temperature can be lowered without affecting deterioration in processing quality. Studies on storage temperature management in relation to the sucrose content of tubers are in progress.
- Cold-sweetened Umatilla Russet tubers can be reconditioned at higher temperatures (e.g. 60°F) at the end of storage to lower reducing sugar content and improve processing quality.

Literature Cited

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