

From Field to Storage: High Quality Carrots
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In response to increasing demand for local vegetables through the winter months, growers are expanding their production of root vegetables for winter storage. Carrots are a widely grown storage crop with a strong market demand. Under ideal conditions carrots can be stored for 6 months, but in sub-optimum storage conditions they suffer from water loss, change in taste and texture, diseases, and sprouting. Growers in New England are using a wide range of harvest and post-harvest practices for carrots. Available storage conditions may be less than ideal, and varieties may differ in their response to different conditions. At the UMass Vegetable Program from 2010-2013, we explored some of the factors that quality in storage, including variety, harvest date, postharvest washing, and storage conditions. See *Carrots for Winter Sales: Varieties, Planting Dates and Post-Harvest Care* by Amanda Brown (Root Crops Session) for details on varieties and dates of harvest. In this article we will cover what we learned about how those factors played out in storage.

2010-2011 Varieties in Storage.

Methods. Six storage carrot varieties (Bastia, Berlanda, Bolero, Canada, Carson, Sugarsnax) were planted on June 28, 2010 and harvested on 4 dates (Sept. 29, Oct. 12, Oct.27, Nov. 10). At harvest, marketable carrots (U.S. No.1 & U.S. No.2) were washed by hand in buckets (with 1/4 cup per 4 gallons) and placed in perforated plastic bags in a cold storage room with temperature at 32-37 degrees F (avg 35F) and RH>95%. Monthly from December through March, we pulled carrots to measure °Brix and water loss. For Brix, slices were frozen, then thawed to release juice. Results. *Water loss* occurred at low levels throughout the storage period, was consistent across varieties, and averaged 5-11% between harvest and March 1. *Brix readings* increased from December through February, and declined sharply in March. While there was variation in Brix readings among varieties, this pattern was consistent.

2012-2013 Storage Case Studies. We used Bolero carrots grown at the UMass Research Farm as a model crop to examine how conditions at four on-farm storages affected carrot quality through the winter months. While these case studies cannot fully address the question of trade-offs between quality and cost, they do offer insight into how different storages affect quality and marketability.

Methods. We seeded Bolero carrots on July 11, harvested on November 13/14, and placed in the storage facilities immediately after harvest. Carrots were stored unwashed or were barrel-washed pre-storage, to match the conditions of each farm's storage. If carrots were stored loose at a farm, we placed ours in mesh bags (10/bag, 4 replicates) to distinguish them from other carrots and placed them with the farm carrots. If carrots were stored in perforated plastic at a farm, we placed ours 10 to a bag in perforated plastic bags. Temperature was monitored with Hobo dataloggers. We removed one set of bags from the storage each month to sample water loss, Brix score, rubberiness, rot, and other measures of carrot quality. We also brought carrots from on-farm storages to the Amherst winter farmer's market in January, February, and March and asked attendees to sample slices of each carrot and rate the carrots based on texture, taste,

and appearance. Carrots were rated on a 1-5 scale, with 1 being poor and 5 being excellent.

Farm Storage Facilities

Farm A: 1300 sq ft underground root cellar, cement walls & spray foam ceiling insulation. Active cooling with ambient air is provided by an 8" pipe with fan, and passive cooling through other openings. Outdoor T remained high through December, and this storage reflected that: T stayed in low 40's until mid deck., between 35 and 40 °F until Jan. 22, 35-38 °F until the end of Feb, and below 40F until March 27. Carrots storage: unwashed in woven plastic grain sacks. Humidity: respiration of stored vegetables, supplemented by wetting the floor.

Farm B: 8' x 8' x 10' tall walk-in cooler, with a compressor, condenser, and fans, standard refrigeration panels and foam-board in the floor. Storage temperature is set at 38F year-round, and our dataloggers showed T was consistent at 36-38 F from harvest through April, dropping as low as 33 during a cold spell in early January. Humidity: water from wet greens soaks into the plywood floor and keeps the storage quite humid. Carrot storage: barrel-washed, stored in 25 lb perforated bags. The farm has been able to store carrots successfully into April or May.

Farm C: underground basement of a large barn, 21' x 47' x ~7' tall, insulated with 4+ inches of spray foam insulation inside the walls and ceiling, as well as aboveground walk-in cold storages. All are heated and cooled by a geothermal system and cold air from outside. Dataloggers showed T dropped steadily from 41F 11/15 to 36 by 12/25 and stayed between 34 and 36 through the first week of April. Carrot storage: unwashed in large macro 34 vented bins on pallets. Humidity: carrots are misted, and shrink-wrapped or simply covered on top with a layer of plastic.

Farm D: a 320 sq ft concrete storage built for high RH, low T storage; ceiling is insulated with foam, sides are flanked by two other coolers, and the back side is insulated by the earth. The cooler is a low velocity unit cooler run on hard-wired electricity. An automated spray system kicks in when the humidity falls too low. Storage T ranged from 31 to 36 °F. Carrot storage: washed at harvest, stored in large bins within 25 lb capacity vented plastic bags. We tested both perforated and mesh bags, placed on top of or nestled in pallets containing farm carrots that were bagged in perforated plastic.

Results. *Water loss* over three months was 13% at Farm A and in carrots in mesh bags at Farm D, compared to less than 2% at Farms B,C, and Farm D for carrots in perforated plastic. The water loss in mesh in the cold, high RH environment for Farm D was unexpected. *Rubberiness* – Carrots that experienced water loss also became 'rubbery'. Marketability was not affected at low levels of rubberiness, but by February, 80% of carrots in mesh bags at Farm D were rated as unmarketable. We found *Brix scores* to be higher in the carrots that experienced greater water loss, likely due to the fact that loss of water meant sugars were concentrated in the water that remained. In *taste tests*, we saw changes over the course of the storage trial period. In January, after two months of storage, the carrots stored under the closest to ideal conditions – at Farm C and at Farm D in plastic – were rated higher in appearance, flavor, texture and preference compared to carrots stored in mesh at Farm D and carrots from the root cellar at Farm A. In February, results were similar except that we found no difference in taste and texture ratings; anecdotally, some people appreciated the crunch and crispness of the carrots that had been stored under ideal conditions, while others noticed the sweetness of the carrots that had experienced

greater water loss. By March, carrots from the root cellar (Farm A) were rated highest in flavor and texture – apparently the higher sugar content was especially noticeable at this point, compared to crispier carrots that were less sweet.

To Wash or Not to Wash. One long-standing debate is on the merits of washing carrots before placing them into storage. The decision to wash carrots before storage, or immediately before sale during the winter months, is usually based on a farm's washing facilities (heated or not) and available labor. In the 2012-13 season, we stored Bolero carrots from the UMass Research Farm (seeded July 10 & harvested Nov. 5) under three postharvest treatments: barrel-washed, hand-washed (scrubbed in a bucket by hand), and unwashed (stored unwashed, and washed just before evaluation). For each treatment, carrots were placed in perforated plastic bags, and stored at 32-34 degrees, 95% RH. For each month in storage, we pulled out designated bags to evaluate rot, staining and lenticel dirt, top sprouting, hair sprouting, water loss, flavor, and crunch, and Brix readings.

Results. *Rot* – There was no effect of treatment on root rot in our 2012-2013 trial – washing did not lead to higher levels of rot. *Staining* – Some staining was apparent in unwashed treatments this year, manifesting as a slight brownish cast on some carrots. However, overall, staining was quite low, and difficult to distinguish from the off-color whitish cast that occurs in older carrots, no matter how they were stored. *Hair sprouting* – In the April sample only, we found higher rates (20-40%) of hair sprouting (white hairs growing along the carrot) in both washed treatments, compared to 2.5% in unwashed. Hair sprouting indicates that the carrot is becoming biologically active, which will render it unfit to eat. *Other variables* – We found no effect of washing treatment on water loss, flavor, lenticel dirt, or top sprouting of carrots.

Discussion and Conclusions. Storing carrots under ideal conditions does a great job of protecting carrots from water loss, and maintaining crunch. We found in our case studies that a simple solution, like a walk-in cooler (Farm B), minimized water loss as well as a specially designed facility (Farms C and D), as long as packaging of the carrots is adequate. Reliance on ambient air for cooling may not achieve the desired low temperatures as quickly as needed, which may increase water loss because the warmer air requires more water to achieve the same relative humidity. Marketability was maintained in all four on-farm storages, even under less than ideal conditions. A limited amount water loss appears to be tolerable and in fact lead to sweeter carrots over time. When water loss was low (5-11% in 2010-11 storage trial, and <2% in 2012-2013 study), we observed a tendency for carrots to decline in sweetness after February.

Carrots can be successfully stored unwashed without significant staining occurring, at least for the Hadley silt loam found in Deerfield MA. This may differ among soil types; in a 2009 washing trial at Jerrico Settlers Farm in Jerrico, VT found increased staining in unwashed carrots. Like Jerrico Settlers Farm, we found that carrots can be stored washed without rot, though there was a slight increase in rot and in 'hairiness' late in the season. Washing by hand or barrel worked equally well. The success of either approach to washing will vary with soil type, storage conditions and storage duration, but it appears that either can work well.