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2. Evaluating Cold Storage Temperatures on Fresh Pack Berry Quality

OBJECTIVE

This project aims to improve post-harvest handling of fresh pack wild blueberries to extend the berries' shelf life by identifying optimal cold storage temperatures for wild blueberries that cannot be kept cold throughout the entire cold chain.

LOCATIONS: Blueberry Hill Research Farm, Jonesboro, ME and Welch Farm, Roque Bluffs, ME
PROJECT TIMEFRAME: July and August 2021 & 2022

INTRODUCTION

Many family-run wild blueberry farms in Maine (20-200 acres) do not have the capital to invest in the development of complete cold chain infrastructure that would extend the shelf life of their berries. A complete cold chain keeps berries at a consistent cold temperature from field to market and requires investment in on-farm cold storage and cold transportation. When berries are cooled and then moved into a warmer space for transport, storage, or sale, this temperature fluctuation accelerates the decline in fruit quality. Growers have indicated that fresh wild blueberry storage temperatures range from 40°F to 70°F, so many growers are hesitant to cool berries because they lack a complete cold chain or on-farm cooling infrastructure.

Wild blueberries are harvested at the peak of ripeness and growers and processors have a short amount of time to get fresh wild blueberries to consumers. Wild blueberries continue to respire after being harvested, and this respiration increases the temperature of the fruit and contributes to its eventual, inevitable decay in quality, where the fruit loses mass and firmness (Tetteh et al., 2004). Thus, slowing the rate of respiration is critical to maintaining higher-quality fruit for longer. The easiest way to reduce fruit respiration (and associated decay) is by lowering the temperature of the fruit: highbush blueberries stored at 80.6°F respire at a rate twenty times higher than that of fruit stored at 40°F (Boyette et al, 1993). Sanford et al. (1991) demonstrated that the ideal storage temperature for wild blueberries is close to 32°F, taking extra care to prevent the fruit from freezing, since that would ruin the fruit destined for the fresh market. Postharvest wild blueberries decay at a slower rate than do highbush blueberries (Sanford et al., 1991), but any loss of saleable product harms small growers. Consumers generally purchase fresh blueberries impulsively and are guided by the visual appearance of the fruit in deciding whether to purchase (Tetteh et al., 2004), so individual growers, local cooperatives, and Maine's entire industry benefit from delivering high-quality fruit to consumers (Wild Blueberry Commission of Maine, n.d.).

This project builds on earlier research into the optimal wild blueberry storage temperature within homemade cold storage units. Earlier research measured fruit quality for 30 days post-harvest in cold storage units and the 2022 season's research focused on the following two questions: A) Which of the cold storage temperatures of 34°F, 40°F, and 50°F best maintains fresh pack pint berry quality over 30 days? and B) Is there a relationship between outdoor/ambient temperatures and the temperatures within the internal storage units? To answer these questions, berry moisture, shriveling, and temperature were measured along with the temperature and relative humidity of five cold storage units throughout the fresh pack harvest season.

For a more thorough explanation of the need for, construction, and costs of the cool temperature storage facilities used at Blueberry Hill Farm, please see the 2020 report summary, entitled "Coolbot Cold Storage Room Construction and Costs" (page 148) and the 2021 report summary entitled, "Improving Shelf Life of Fresh Pack Maine Wild Blueberries" (page 200).

Image 1. View inside the cold storage unit with fruit stored in molded paper pulp pint containers.

METHODS

Part 1. 36-Day Storage of Fresh Pack Pints

Photographs and visual inspection were used in conjunction with long-term storage unit temperature and relative humidity measurements to quantify fruit quality. This study was conducted at the Blueberry Hill Farm Experiment Station (BHF) in Jonesboro, Maine and at Welch Farm in Roque Bluffs, Maine. At BHF, there are three 8ft x 8ft cold storage units, constructed in 2020 and 2021. At Roque Bluffs, there is one refrigerated truck trailer (8ft x 24ft; unit 2, see below) and one 8ft x 8ft cold storage unit, constructed in 2021.

Table 1. Summary of cold storage unit specifications.

Cold storage units at Blueberry Hill Farm		
1	2	3
34°F	40°F	50°F
16,000 BTU	12,000 BTU	12,000 BTU
R-10 (doubled)	R-10 (doubled)	R-10 (doubled)
Cold storage units at Welch Farm		
N/A	1	2
	40°F	46-56°F
	12,000 BTU	12,000 BTU
	R-10 (doubled)	R-10 (doubled)

Pints were picked up from Welch Farm on August 2 after being hand raked on August 1, stored overnight in a cold storage room at 50°F in wooden bins (lacking slats for ventilation), and finally were run through the fresh pack line on August 2, when the berries were transferred to pint-size molded pulp produce baskets. These pints were then transferred to BHF, where they were photographed and then thirty pints were stored uncovered on one shelf with pints directly abutting each other. A handheld digital thermometer with moveable humidity and temperature probes was placed in each unit; the temperature probe was buried in the berries of one pint and remained there for the duration of the study. The humidity probe remained exposed to the atmosphere.

Image 2. Winnowed and cleaned berries stored in a pint-size molded paper pulp produce basket from Welch Farm.

Pints were sampled six times between August 2 and September 6 on August 2, 5, 15, 25, 30 and September 6 for a total of 36 storage days. Measures taken during each visit included cold storage unit air temperature as displayed on the air conditioning units, cold storage unit air temperature as displayed on a portable digital thermometer, and photos of 15 random pints from each cold storage unit for later measurement of berry moisture and shrinkage.

Table 2. Summary of pint samples.

Fruit storage size	**Harvest date**	**Dates sampled**	**Date removed**
Pints	August 2	August 2, 5, 15, 25, 30 & September 6	September 6

Photographs of each pint during each sampling event were processed using FIJI/ImageJ's cell counter mode (FIJI software version 2.9.0, Madison, WI). The berries in the images were counted using the cell counter mode, which had three counter options: total fruit, wet fruit, and shriveled fruit. Every fruit was hand-counted using the program's total fruit mode, and when appropriate, the fruit was also counted using the wet or shriveled berry counters. Each photo then generated three numbers, which could be compared across time and treatment: total fruit, wet fruit, and shriveled fruit.

Part 2. Ambient Temperature & Cold Storage Unit Temperature

Onset HOBO (Onset Computer Corporation, Bourne, MA, USA) temperature and relative humidity sensors (MX2300) were placed in each cold storage unit to continuously track these metrics over time. Three total sensors were placed in the Welch Farm fresh pack processing area and both cold storage units in late morning August 2. These sensors were retrieved from Welch Farm at midday on September 15. Four total sensors were placed in the BHF garage and all three cold storage units in late morning August 2. Sensors were retrieved from BHF on the morning of September 6.

Data analysis

Treatment differences in berry wetness across all dates were evaluated using a full-factorial repeated-measures mixed model design in JMP (JMP®, Version 16.0, SAS, Cary, NC, USA), followed by a Tukey's pairwise comparison (Figure 1). Here, the full-factorial model tested the effects of date, treatment and any interaction between date and treatment. Berry wetness data passed assumptions for parametric statistical testing and a transformation was not required. Treatment differences were established by date (Figure 2) using a Standard Least Squares Analysis of Variance followed by a Tukey's Pairwise comparison.

Due to the nature of the data collected, the berry shriveling data failed the assumption of a normal distribution required to run parametric statistical tests. Transforming the data via a square root transformation did not improve the distribution. Statistical tests were carried out on the untransformed data despite non-normality after establishing there were no serious problems with the data. Treatment differences were established by date (Figure 3) using a Standard Least Squares Analysis of Variance followed by a Tukey's Pairwise comparison.

RESULTS

Part 1. 30-Day Storage of Fresh Pack Pints

The wetness and shriveling of the berries increased as cold storage temperatures increased (Figure 1). The wetness of berries was 47% at 34°F, 51% at 40°F, and 53% at 50°F. The shriveling of berries was 52% at 34°F, 53% at 40°F, and 59% at 50°F.

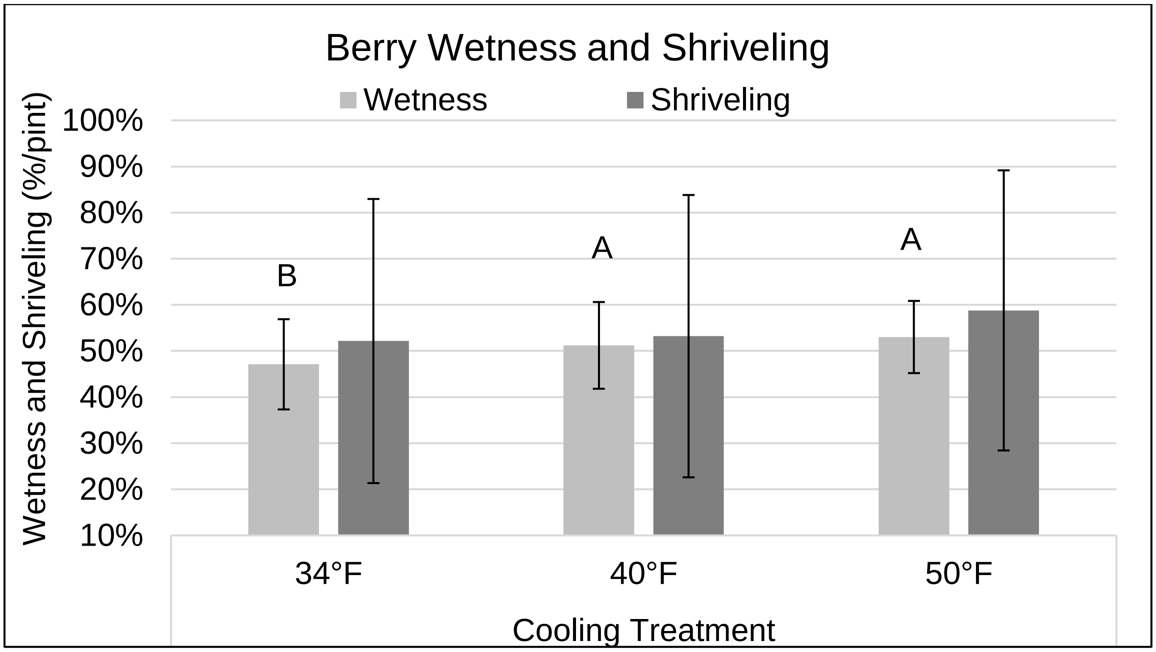

Figure 1. Average berry wetness (%/pint) and berry shriveling (%/pint) by cold storage unit temperature treatment, measured August 2 to September 5, 2022. Letters indicate significant differences at the 0.05 level of significance. Treatment differences in berry shriveling were not significant. Error bars represent the standard error of the mean.

The wetness of berries changed over time, decreasing after initial placement before climbing back up to levels near the initial wetness (Figure 2). When placed on August 2, 2022, pints in all temperatures had berry wetness levels of 59%. Berries in the 34°F unit (lightest gray data) dropped from 59% wetness on August 2 to 41% on August 5 before climbing to 42% on August 15, 49% on August 25, 51% on August 30, and peaking at 53% on September 6. Berries in the 40°F unit (lightest gray data) dropped from 59% wetness on August 2 to 44% on August 5 before climbing to 43% on August 15, 53% on August 25, peaking at 61% on August 30, and dropping to 57% on September 6. Berries in the 50°F unit (medium gray data) dropped from 59% wetness on August 2 to 49% on August 5 before climbing to 45% on August 15, 54% on August 25, peaking at 61% on August 30, and dropping to 57% on September 6.

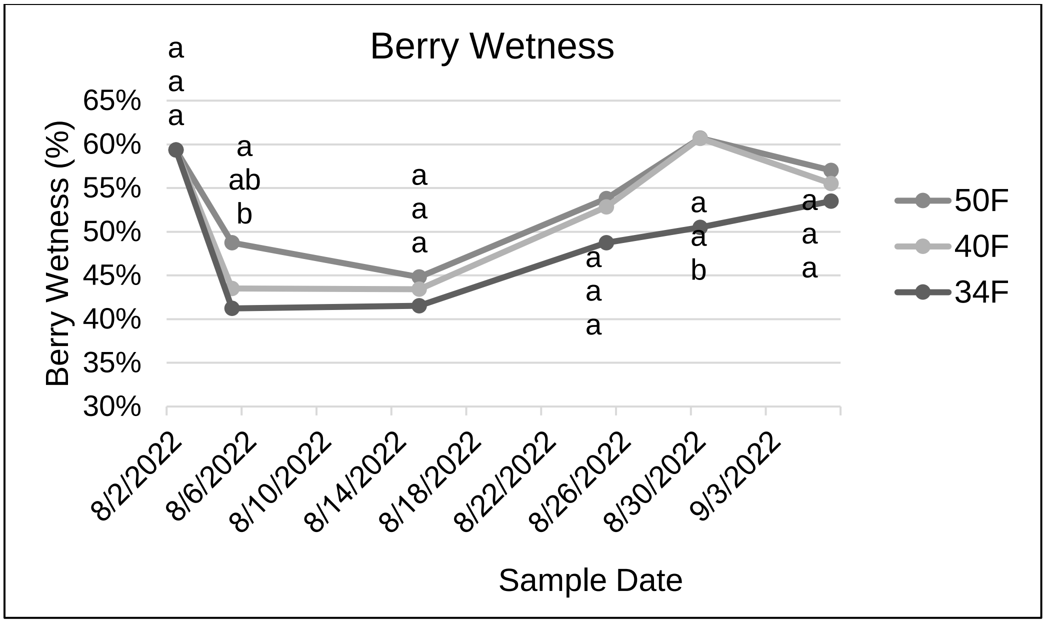

Figure 2. Average berry wetness (%/pint) by date and cold storage unit temperature. Letters indicate significant differences at the 0.05 level of significance and are to be compared across treatments by date (dates are to be compared separately). Letters correspond to legend order (50°F: top letter, 34°F: bottom letter).

The shriveling of berries steadily increased over time (Figure 3). When placed on August 2, 2022, pints in all temperatures had no shriveling at all. Berries in the 34°F unit (darkest gray data) increased from 0% shriveled on August 2 to 1% on August 5 before jumping to 37% on August 15, 66% on August 25, 72% on August 30, and peaking at 85% on September 6. Berries in the 40°F unit (lightest gray data) increased from 0% shriveled on August 2 to 1% on August 5 before jumping to 40% on August 15, 64% on August 25, 76% on August 30, and peaking at 85% on September 6. Berries in the 50°F unit (medium gray data) increased from 0% shriveled on August 2 to 1% on August 5 before jumping to 59% on August 15, 71% on August 25, peaking at 82% on August 30, and dropping slightly to 81% on September 6.

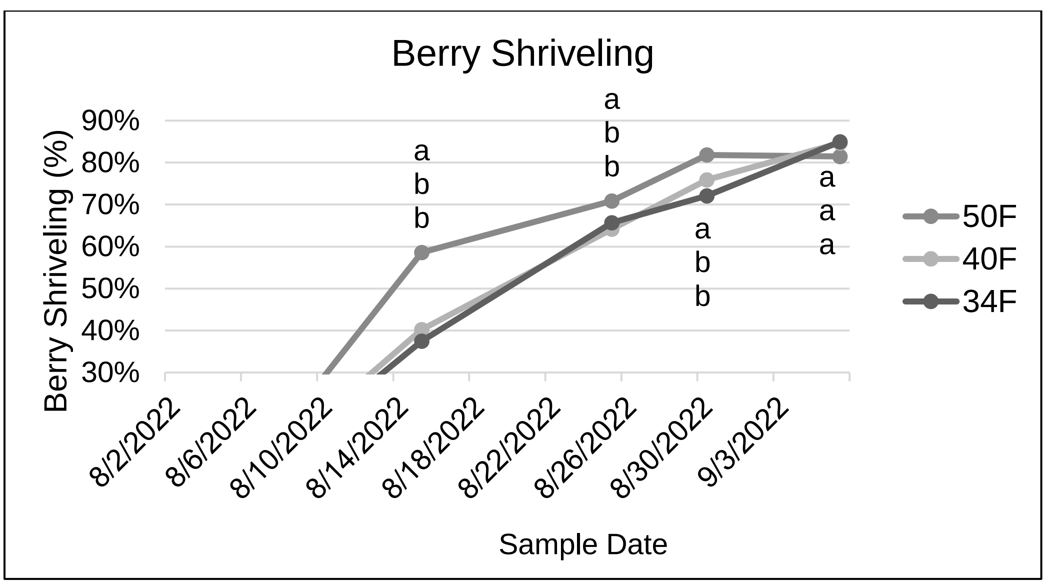

Figure 3. Average berry shriveling (%/pint) by date and cold storage unit temperature. Letters indicate significant differences at the 0.05 level of significance and are to be compared across mulch treatments by date (dates are to be compared separately). Letters correspond to legend order (50°F: top letter,

34°F: bottom letter). Shriveling values from the August 2 and August 5, 2022 sample dates were between 0 and 1%.

<u>Part 2. Ambient Temperature & Cold Storage Unit Temperature</u>

There are clear, sharp changes in the ambient temperature that coincide with sudden changes in the internal temperatures of the cold units (Figure 4). When the ambient temperature (darkest gray dots on graph below, top series of data) spiked at temperatures higher than 81°F from 11 AM to 4 PM on August 16, 2022, the temperatures in the cold units also increased during that same timeframe: 34°F (lighter medium gray dots on graph below, bottom series of data) increased to 40.39°F at 11 AM before peaking at 41.35°F at 3 PM; 40°F (lightest dots on graph below, third series of data from top) increased to 42.85°F at 11 AM before peaking at 43.33°F at 3 PM; 50°F (darker medium gray dots on graph below, second series of data from the top) increased to 49.22°F at 11 AM before peaking at 50.36°F at 3 PM.

Changes in the ambient temperature yielded similar changes in the temperatures recorded in the cold storage units, such as the decrease in ambient temperature in the morning of August 18 which occurred at the same time there was a decrease in the 40°F unit's temperatures, and the large increase in ambient temperature during the afternoon of August 20 which caused increases in all cold storage units.

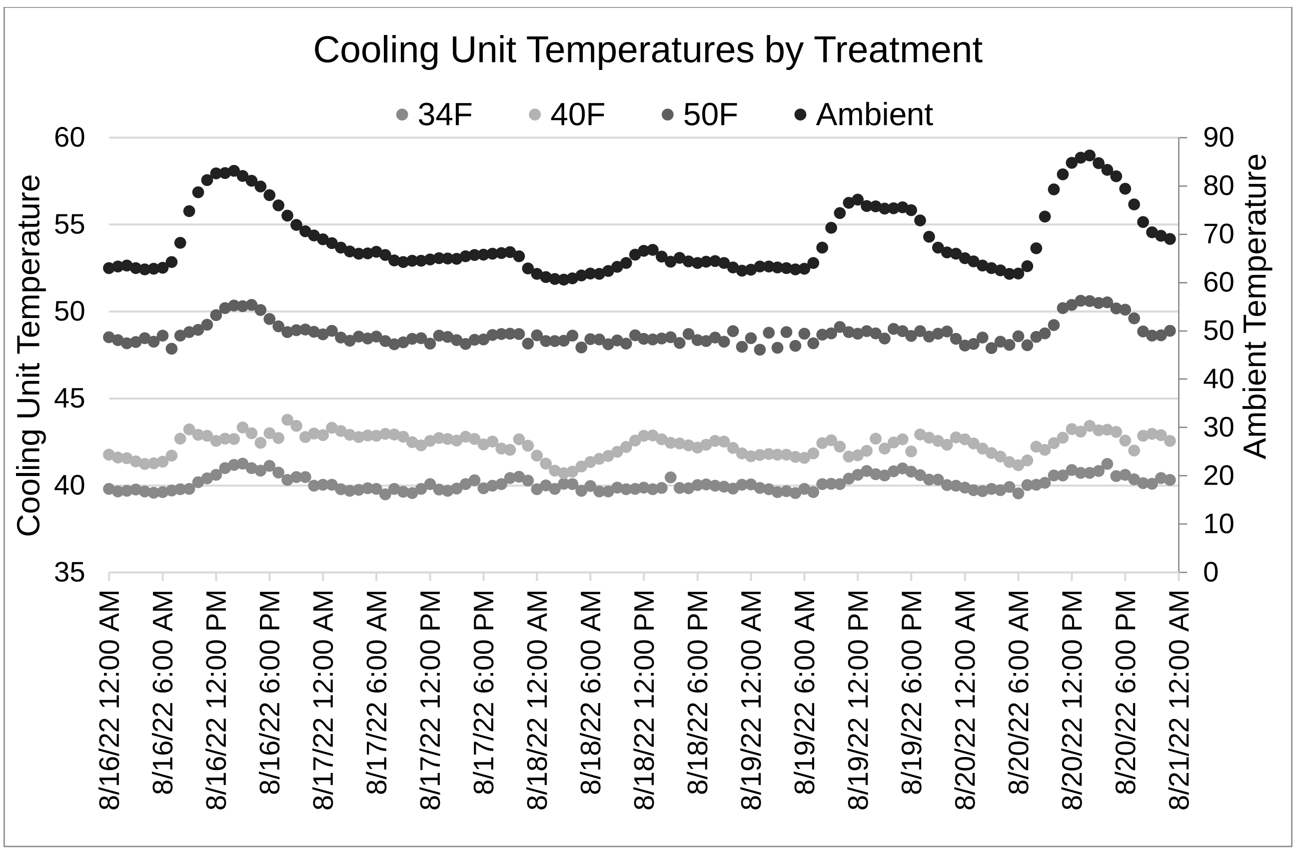

Figure 4. Hourly cooling unit temperatures (°F) by treatment collected from August 16 to August 21, 2022. Ambient temperature was collected outside the cold units reflecting the temperature of the open-air barn where the cooling units are installed at Blueberry Hill Farm, Jonesboro, ME.

DISCUSSION

Surface moisture on fruit was significantly lower from day 4 through 36 in the 34°F cold storage unit. Across storage temperatures, surface moisture started high most likely due to the break in the cold chain while being run through the fresh pack line and transported from Roque Bluffs to Jonesboro. The transport car had air conditioning on but temperature fluctuation still occurred. Day time outdoor temperatures on August 1 and 2 peaked at 91°F and 83°F, respectively. As storage in the cold storage units at BHF began, the surface moisture trend dropped and then increased from August 26 – September 6th at all storage temperatures. Surface moisture may have increased as fruit respiration reached a certain point or ambient humidity which was an average of 81% from August 26th to September 6th, may have impacted fruit inside cold storage units. During the last 12 days of the experiment, average relative humidity was 82% in the 34F cold storage unit and 83% in both the 40F and 50F cold storage units.

As expected, shriveling increased consistently over time across all storage temperatures. Berries continue to respire after being harvested contributing to the fruit drying out. Respiration is the breakdown of sugars into CO2 and water which leaves the fruit through stomata. Thus, the more time fruit is stored, the more shriveled it will become. The lack of any significant shriveling from August 2 to 5 across all storage temperatures indicates growers may have a window of a few days before shriveling becomes visible on the top layer of fruit. The jump in shriveling across all storage temperatures observed on August 15 indicates the decay of the fruit accelerated. The largest gains in shriveling were observed in the 50°F unit, where the warmer temperatures did not slow down shriveling/respiration rates as much as the cooler units did.

Substantial and sudden changes in ambient temperature often yielded similar changes in the temperatures inside the cold storage units. Some units seemed to have more of a relationship to the ambient temperatures than did others, the two colder units (34°F and 40°F) seemed more likely to fluctuate with ambient temperature than did the 50°F unit.

CURRENT RECOMMENDATIONS

- In order to maintain quality for the longest time, wild blueberries should be stored at 34°F where the least surface moisture will develop.
- In this situation, wild blueberry quality was highest during the first 5 days of storage and quality began to really decline on day 14.

NEXT STEPS

- Conduct engineering research to improve rake and harvester technology to reduce damage to berries in the field.
- Study reducing the that time berries spend in the field and in process before cooling to maintain quality longer.
- Tweak fresh pack lines using new and old lines for fresh pack line efficiency.

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