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Postharvest characteristics of 'MN80' (Triumph™) apple fruit compared to 'Cortland' and 'Honeycrisp'

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Abstract

'MN80', a cross between 'Honeycrisp' and 'Liberty', a newly-released apple sold under the Triumph trademark, is meant to be marketed primarily to home gardeners and small-scale commercial orchards. It was selected for release based on its fruits' resistance to apple scab, thus requiring less spraying than scab-susceptible cultivars. The quality of 'MN80' fruit from two growing locations over multiple years was assessed at harvest and after storage for four months at 0-1 °C and 4-5 °C. Mean firmness of Wisconsin-grown 'MN80'fruit decreased as harvest week increased, but mean fruit fresh weight and total soluble solids concentration (SSC) remained the same over harvest time, which was also observed for ME-grown fruit. Fruit stored at 4-5 °C exhibited more shrivel and loss of firmness than fruit stored at 0-1 °C. Percentages of fruit showing internal browning and soft scald in storage increased with harvest date for ME-grown fruit in 2019 but not 2021. Consumer sensory panels evaluating newly-harvested fruit liked 'Honeycrisp' and Maine-grown 'MN80'fruit best, followed by Wisconsin-grown 'MN80'fruit, then 'Cortland' fruit. However, after 4 months of storage, Maine-grown 'MN80' fruit had the highest overall liking scores of all the stored cultivars. Mean sensory attribute scores of Maine- and Wisconsin-grown 'MN80' fruit changed little with storage, whereas stored 'Honeycrisp' and 'Cortland' had lower scores than newly-harvested fruit. For all cultivars, storage temperature had no effect on sensory attribute scores. These data suggest that 'MN80' fruit retain characteristics that appeal to consumers between harvest and 4-5 months of cold storage.

'MN80' (Triumph™, Bedford et al., 2021), a cross between 'Honeycrisp' and 'Liberty', is the newest release from the University of Minnesota apple breeding program. 'Liberty', a cross between 'Macoun' and Purdue 54-12, was created in a cooperative project between the Department of Pomology and Viticulture and the Department of Plant Pathology at the New York State Agricultural Experiment Station in Geneva (Lamb et al., 1978). It has resistance to apple scab, cedar apple rust, fire blight, and mildew, so is a good cultivar for reduced fungicide spray programs, but may need management of other diseases, such as sooty blotch and fly speck. 'MN80' has two genes for scab resistance (MN Agric. Expt. Station, 2021), so is being marketed to home consumers and small orchards where apple scab is prevalent.

The fruit of 'MN80'are red and globose, and ripen about a week later than 'Honeycrisp' fruit, which are known for a crisp texture that can be maintained through six months of cold storage (Tong et al., 1999). Inheritance of this trait by 'MN80' fruit would enhance its attraction to home orchardists and small acreage farmers with retail farm markets. However, 'Honeycrisp' fruit are subject to various storage disorders, such as bitter pit, soft scald, and soggy breakdown (Moran et al., 2010; Watkins et al., 2004), and inheritance of susceptibility

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to these disorders would lead to postharvest losses for growers unable to use methods that could mitigate the disorders. The work described here was initiated to characterize the harvest and postharvest qualities of 'MN80' fruit, and determine its possible appeal for a local, retail markets. In the upper Midwest and Northeast USA, 'Honeycrisp' and 'Cortland' are currently grown for local markets. Therefore, harvest quality and postharvest performance of 'MN80' were compared with these two cultivars.

Materials and Methods

Materials. 'MN80' apple fruit were grown at the University of Wisconsin Peninsular Agricultural Research Station in Sturgeon Bay, WI (45° 9' 43" N, 87° 22' 56" W), and

Table 1. Dates of harvests in ME and WI of 'MN80' fruit and types of experiments done in ME, MN, and WI done in 2017, 2018, and 2021. 'Cortland' and 'Honeycrisp' fruit were also harvested in ME in 2021, with similar measurements made at harvest and after storage as with 'MN80' fruit.

Year	Harvest Location	Harvest Dates	Measurements at Harvest	Storage Location and Temperature (°C)	Measurements after Storage
2017	WI	29 Sept., 6 Oct., 13 Oct.	firmness, FW, SSC, SPI	WI, 2 °C	firmness
2018	WI	21 Sept., 28 Sept., 1 Oct., 5 Oct., 12 Oct., 19 Oct.	firmness, FW, SSC, SPI	WI, 2 °C	firmness
2019	ME	24 Sept., 8 Oct., 21 Oct.	firmness, FW, SSC, SPI	ME, 0.5 and 4 °C	disorders, firmness, SSC
2021	WI	14 Oct.	firmness, FW, redness, SSC, SPI	MN, 0-1 and 4-5 °C	disorders, firmness, SSC, sensory evaluations

ME	27 Sept., 6 Oct.	firmness, FW, redness, SSC, SPI	ME, 1 and 4 °C; MN, 0-1 and 4-5 °C	disorders, firmness, peel color, SSC, sensory evaluations

FW is fresh weight, SSC is soluble solids concentration, and SPI is starch pattern index.

the University of Maine Highmoor Farm in Monmouth, ME (44° 13' 51" N, 70° 4' 5" W). 'MN80' trees in WI were on 'Budagovsky 9' rootstock planted in 2014, while ME trees were grafted onto 'Malling 26' rootstock planted in 2014.

Dates of harvests, storage conditions and locations, and measurements made at harvest and after storage are shown in Table 1. Trees in WI were harvested in 2017 on 29 Sept., 6 Oct., and 13 Oct., in 2018 on 21 Sept., 28 Sept., 1 Oct., 5 Oct., 12 Oct., and 19 Oct., and on 14 Oct. 2021, comparable to the third harvest time in 2017 and the fifth harvest time in 2018. Only four trees had fruit in 2017 and 2018, so all available fruit were eventually picked over the course of each harvest period. The numbers of fruit that were harvested at each date allowed for sampling at harvest and each of the storage periods each year. For each harvest date, 10 and 15 fruit were picked in 2017 and 2018, respectively, and pooled from the four trees. Only fruit with well-developed red peel color were harvested at each date. All fruit harvested in 2021 (160 total) were shipped to MN for storage and consumer sensory testing.

'MN80' fruit in ME were harvested 24 Sept., 8 Oct. and 21 Oct in 2019. In 2019, five trees were harvested on the first two dates, but due to lack of fruit, only one tree was harvested on the last date. Harvest dates in 2021 were 27 Sept. and 6 Oct. Maine harvests in 2021 also included 'Cortland' fruit on 27 Sept. and 6 Oct., and 'Honeycrisp' fruit on 15 Sept. and 28 Sept. 'Honeycrisp' fruit were conditioned for 7 days at 20 °C in ME which was the ambient temperature in the conditioning room which does not have temperature control and represents conditions for most small farms in Maine. In 2021, a subset of 'Cortland' apples from harvest 1, 'MN80' from harvest 2 and 'Honeycrisp' harvested 8 Oct. were sent to MN for consumer sensory testing. The third harvest for 'Honeycrisp' apples for consumer testing was selected for improved peel color (89%) compared with the first two harvests. All shipped fruit arrived in MN within 3 days of shipment.

Maturity assessments. In 2017 and 2018, fresh weight, firmness, starch content, and total soluble solids concentration of WI-grown 'MN80' fruit were measured at harvest using a total of five replicate fruit per harvest, randomly chosen from the pool of harvested fruit. SSC was measured on a composite sample of juice from the five apples. In 2021, 10 'MN80' fruit shipped from WI were chosen at random (from 160 total fruit), and assessed for fresh weight, redness (%), firmness, total SSC, and starch content upon arrival in MN.

In ME, five single-tree replications were used in 2019, with 10 to 35 fruit harvested throughout the canopy per tree at each harvest date, avoiding the few poorly colored fruit. Five fruit from each replication were used for at-harvest assessments and the re-

mainder was placed in cold storage. In 2021, a pooled sample of 10 fruit from five trees of each cultivar were harvested at each harvest date. Ten fruit per cultivar and harvest date were used for at-harvest assessments, and the remainder were divided into three replications and placed in cold storage. Each cultivar and harvest date had 10 to 30 fruit in each replication. Assessments were made of fresh weight, firmness, starch content, and total SSC, and done on the same days as harvest.

Flesh firmness was measured on two opposing peeled sides of each fruit using drill press-mounted penetrometers (FHT 803, Test Equipment Depot, Melrose, MA in ME in 2019 and EPT-1, Lake City Technical Products, Kelowna, BC in ME in 2021; FT30, Wagner Instruments, Greenwich, CT in MN; and FT327, McCormick Fruit Tech, Yakima, WA in WI), all equipped with 11-mm diameter tips. SSCs were measured using hand-held temperature-compensated refractometers (PAL-1 3810A, Atago, Tokyo, Japan in ME; ATC-1E, Atago, in MN; and REF103, General Tools and Instruments, L.L.C., Secaucus, NJ in WI) from juice expressed during pressure testing. SSC was measured on individual fruit in MN, and on a single collection of juice from five fruit in WI and 10 fruit in ME. For starch staining, a cross-section of each fruit was dipped or sprayed with potassium-iodine solution, and visually rated (Blanpied and Silsby, 1992). In addition, the index of absorbance difference (I_{AD}) was measured in ME on two opposite sides of each fruit, at the interfaces of red and green peel of each apple using a Delta Absorbance Meter® (Sinteleia, Bologna, Italy).

Storage. WI-grown fruit were stored at 2 °C under normal atmospheric conditions in 2017 and 2018. In 2021, 'MN80' fruit shipped from WI were placed in 6 boxes, with 25 fruit per box. Three boxes were stored at 0-1 °C, and three boxes were stored at 4-5 °C. Of the fruit shipped from ME, 10 to 12 fruit of each cultivar were stored at 0-1 °C, and another 10 to 12 fruit of each at 4-5 °C. Additionally, fruit were stored in ME at 0.5 °C for five months in 2019 and at 0.5 and 4 °C for four months in 2021. All fruit were stored under normal atmospheric conditions. After removal from storage plus 1 and 7 days at 17 °C, fruit firmness and total SSC were measured on 5 to 10 individual fruit per cultivar, harvest data and temperature (ME-stored fruit only). Occurrence of storage disorders was measured on 10 to 30 fruit from each cultivar, harvest date and storage temperature.

Sensory evaluations. Sensory evaluations were performed by 117 panelists on 21 Oct. 2021 and by 96 panelists on 28 Jan. 2022 at the Sensory Center of the University of Minnesota. The University of Minnesota Institutional Review Board approved all recruiting and experimental procedures of all sensory tests. Participants were screened to ensure that they did not have food allergies or sensitivities, were at least 18 years old, and liked and consumed apples. They were compensated $10.00 for completing the tasting. Fruit assessed just after harvest were delivered to the Sensory Center and stored at 4 °C for 24 h prior to evaluations. Fruit that had been in storage for 4 months were delivered to the Sensory Center and stored there at 4 °C for 48 h prior to testing.

For all fruit used for sensory tests, samples of the three cultivars were prepared throughout the day of testing and served at room temperature. To prepare the samples, Sensory Center staff washed the apples; cut each fruit into 8 wedges, removing the core; and cut each wedge into three or four pieces, depending on the size of the apple. The pieces were placed in a bowl, sprinkled with anti-browning powder (BallFruit-Fresh® Produce Protector, Rubbermaid Inc., Atlanta, GA), and then two pieces were placed into a translucent 59 mL cup (PC200, Fabri-Kal, Kalamazoo, MI) labeled with the particular apple's sample code. One sample of each cultivar was placed on a tray labeled with a participant's ballot number and arrange from left to right in the order in which the participant was to taste the samples. Tasting order was based on a William's Latin Square across

participants to account for carryover and order effects.

Liking ratings were made on 200-point labelled affective magnitude scales with "Greatest Imaginable Dislike" = -100, "Greatest Imaginable Like" = 100 and the midpoint "neutral" = 0. Intensity ratings were made on a modified 51-point magnitude scale from no intensity to 51 = extreme intensity.

Statistical analyses. Data for WI-grown fruit were analyzed using analysis of variance or linear mixed-effects models using the lm function if normality of residuals could not be satisfied, with R statistical software (RStudio version 1.4.1106 for Ubuntu Bionic, PBC, Boston, MA). Separation of means used Tukey's honestly significant difference tests. Because the numbers of harvest dates differed each year, data for each year were analyzed separately. Since all available fruit on all available trees were harvested in 2017 and 2018, and data from individual fruit were collected, an individual fruit was considered as a replicate. Initial models were $T = \eta + \mu + \eta\mu + \varepsilon$, where T, η, and μ represented trait measured, harvest date, time of measurement (at harvest and the storage periods), the interaction of the two terms, and the residual term, respectively. After storage times were found to have no effects on the measured traits, the models were simplified to $T = \eta + \varepsilon$.

Maturity, quality and disorder incidence data in ME were analyzed using SAS statistical software (version 9.4, SAS Institute, Cary, NC). Data were log or arcsine transformed if needed. Data for 2019 and 2021 were analyzed separately.

Data from sensory tests were analyzed using analyses of variance (ANOVA) with R (harvest data) or SAS (stored fruit data) statistical software, with intensity ratings as the dependent variable and participant, taste position, and apple as the independent variables. Tukey's honestly significant difference tests were used to obtain mean separations.

Results and Discussion

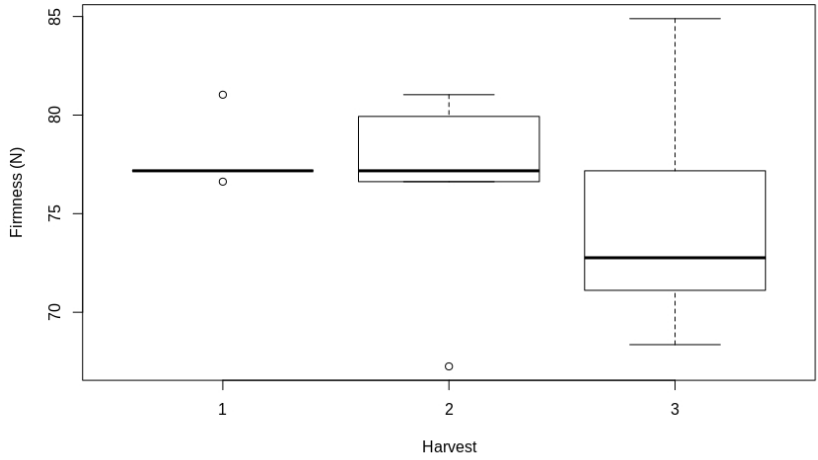
Maturity Assessments. Mean fresh weights of WI-grown 'MN80' fruit were similar in 2017 and 2018, and among harvests for those years (Table 2). In 2017, mean fruit firmness did not differ among harvests (Fig. 1A), but in 2018 mean firmness decreased from the first harvest to the last four harvests. The mean fruit firmness of the last five harvests were not different from each other. (Fig. 1B). Starch index was lower for the first harvest compared to the other harvests in 2017 (Table 2), and unsurprisingly, increased with harvest time in 2018. Although analyses resulted in a statistical difference in starch index between

Table 2. Mean fresh weights and total soluble solids concentration (SSC) of WI-grown 'MN80' fruit in 2017 and 2018. In 2017, fruit were harvested on 29 Sept., 6 Oct., and 13 Oct., and in 2018, fruit were harvested on 21 Sept., 28 Sept., 1 Oct., 5 Oct., 12 Oct., and 19 Oct. Fresh weight values are means ± sd of five replicate fruit. For SSC, only one measurement was made per harvest time.

Harvest	2017			2018		
	Fresh Weight (g)	SSC (%)	Starch Index	Fresh Weight (g)	SSC (%)	Starch Index
1	204 ± 27	13.4	3.8 ± 0.8 c[z]	230 ± 50	12.8	3.8 ± 0.8 c
2	214 ± 21	12.2	6.6 ± 0.6 a	204 ± 43	14.0	5.2 ± 1.1 c
3	223 ± 37	13.0	5.2 ± 0.8 b	229 ± 28	12.2	4.8 ± 0.8 c
4		No harvest		229 ± 34	12.2	6.0 ± 0.7 bc
5		No harvest		232 ± 32	13.0	8.0 ± 0.0 a
6		No harvest		235 ± 29	12.2	7.6 ± 0.6 a

[z]Means within columns followed by common letters do not differ at the 5% level of significance, by Tukey's HSD.

A



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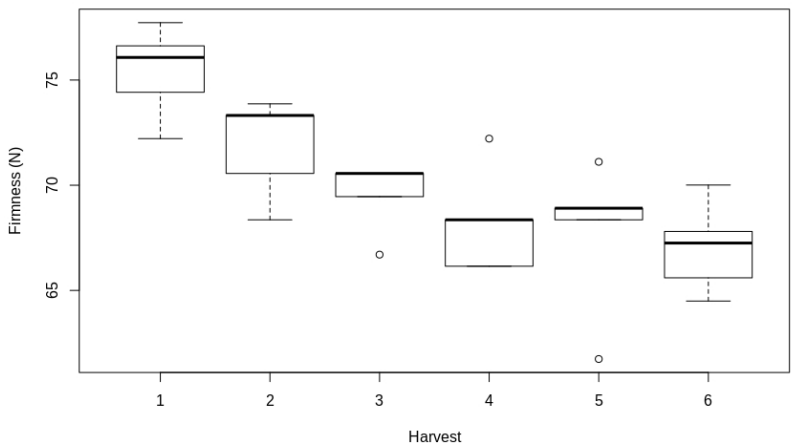

Fig. 1. Box plots for firmness of WI-grown 'MN80' fruit measured at harvests on 29 Sept., 6 Oct., and 13 Oct. in 2017 (A) and on 21 Sept., 28 Sept., 1 Oct., 5 Oct., 12 Oct., and 19 Oct. in 2018 (B). In 2018, the firmness of fruit harvested last was less than from the first harvest ($P = 0.002$), but not the second harvest. Firmness of fruit harvested in 2017 did not differ among harvest times.

Table 3. Fruit fresh weight, soluble solids concentration (SSC) and starch pattern index at harvest of ME-grown 'MN80' fruit harvested on 24 Sept., 8 Oct., and 12 Oct. 2019, and 'MN80' and 'Cortland' fruit harvested on 27 Sept. and 6 Oct. 2021.

Cultivar	Harvest	2019			2021		
		Fresh Weight (g)	SSC (%)	Starch Index	Fresh Weight (g)	SSC (%)	Starch Index
MN80	1	191 ± 13 b[z]	13.5 ± 0.2 b	2.3 ± 0.4 c	234 ± 8	14.0	4.9
	2	217 ± 19 ab	14.1 ± 0.3 ab	3.6 ± 0.5 b	254 ± 18	13.7	6.2
	3	256 a	16.0 a	7.6 a	--	--	--
Cortland	1	--	--	--	235 ± 9	14.0	2.5
	2	--	--	--	222 ± 18	11.0	3.4

[z] Means within columns followed by common letters do not differ at the 5% level of significance, by Tukey's HSD. Values are means ± sd for 10 fruit from each of five single-tree replications, except harvest 3 in which there was only one replication. For total SSC, firmness and starch index in 2021, only one set of 10 fruits was measured per harvest time.

harvests 2 and 3 in 2017, that difference is most likely not biologically meaningful. In 2021, trees in WI were harvested only once, on 14 Oct. Mean fresh weight, and total SSC and starch index of the fruit were 190.2 ± 86.0 g, 66.6 ± 025 N, and 13.6 ±1.6% (n = 10 for all traits). Red overcolor of the fruit covered 90 ± 9% (n = 10) of the surface, and ≤ 5% of the flesh surface of all tested fruit showed starch staining, indicating that the fruit had reached maximum ripeness. Despite the once-over harvest, fresh weight, firmness, and total SSC of fruit harvested in 2021 was comparable to that of fruit harvested at analogous times in 2017 (last harvest) and 2018 (fifth harvest). These data suggest that it may be best to harvest 'MN80' fruit in late Sept. or early Oct. in the upper Midwest, and multiple harvests are not required.

In ME, fresh weights of 'MN80' increased with later harvest date in 2019, but not in 2021 when only two dates one week apart were compared (Table 3). Fruit size appeared to be larger in 2021 than in 2019 when comparing similar harvest dates. SSC increased with later harvest date in 2019, but not in 2021. Starch index increased, indicating greater starch breakdown with later harvest, but appeared to be more advanced in 2021 compared to similar dates in 2019. In 2019, I_{AD} was 1.23, 1.00 and 0.60 for harvests 1, 2 and 3, respectively, and decreased with later harvest date. In 2021, I_{AD} was 0.86 and 0.76 for harvests 1 and 2, respectively. Based on starch index and I_{AD}, maturity was advanced in 2021 compared to 2019 at similar harvest dates.

Storage. Storage did not affect firmness or total SSC of WI-grown fruit in 2017 and 2018. Firmness of stored fruit varied with harvest time in a similar pattern as at initial harvest (data not shown). In 2021, firmness and SSC of stored WI-grown fruit were similar to that of fruit measured at harvest. Storage temperature (0-1 or 4-5 °C) did not affect firmness or total SSC of WI-grown fruit. Mean firmness (± sd) were 71.54 ± 4.9 and 76.4 ± 8.8 N, and mean total SSC (± sd) were 12.4 ± 1.8 and 13.0 ± 1.4% after 4 months of 0-1 C and 4-5 °C storage, respectively. These data suggest that 'MN80' fruit characteristics remain stable between harvest and 4 months of cold storage.

In 2019 in ME, 'MN80' total SSC was higher and firmness was lower with later harvest at both 1 and 7 days after removal from storage at 0.5 °C (Table 4). With the third harvest, there was insufficient fruit free of disorders for quality measurement at day 7. In 2021, storage temperature had little influ-

Table 4. Soluble solids concentration (SSC) and fruit firmness after five months of cold storage at 0.5 °C in ME-grown 'MN80' fruit harvested on 24 Sept., 8 Oct., and 12 Oct. 2019 and stored in ME. Fruit were assessed 1 or 7 days after removal from storage.

Harvest	SSC (%)		Firmness (N)	
	Day 1	Day 7	Day 1	Day 7
1	14.0 ± 0.2 b[z]	14.8 ± 0.5 b	97 ± 2 a	95 ± 3 a
2	15.5 ± 0.1 ab	15.1 ± 0.4 a	90 ± 1 b	88 ± 4 b
3	15.9 ± 0.7 a	--	87 ± 4 b	--

[z] Means within columns followed by common letters do not differ at the 5% level of significance, by Tukey's HSD. Values are the mean ± sd of five single-tree replications except harvest 3 in which there were four replications.

Table 5. Fruit quality after four months of cold storage at 0.5 °C in ME-grown 'MN80' and 'Cortland' fruit harvested on 24 Sept., 8 Oct., and 12 Oct. 2021 and 'Honeycrisp' harvested 15 and 28 Sept. 2021 with 7 days of conditioning at 20 °C. All storage and measurements were made in ME, either 1 or 7 days after removal from storage.

Cultivar	Harvest	SSC (%)[z]		Firmness (N)		Peel color (%)
		Day 1	Day 7	Day 1	Day 7	Day 1
MN80	1	15.8 ± 0.6 a[y]	14.9 ± 0.6 a	81 ± 13 a	79 ± 3 a	71 ± 6 a
	2	14.6 ± 0.4 b	14.6 ± 0.7 a	71 ± 1.7 b	73 ± 3 b	72 ± 2 a
Cortland	1	13.6 ± 0.7 c	13.4 ± 0.5 b	46 ± 2 e	48 ± 1 e	60 ± 6 ab
	2	12.6 ± 0.6 d	12.0 ± 0.4 c	48 ± 2 e	46 ± 2 e	48 ± 11 b
Honeycrisp	1	11.2 ± 0.4 e	11.1 ± 0.3 cd	67 ± 2 c	68 ± 2 c	64 ± 2 a
	2	11.2 ± 0.3 e	11.0 ± 0.5 d	60 ± 2 d	59 ± 1 d	69 ± 5 a

[z] SSC is soluble solids concentration.

[y] Means within columns followed by common letters do not differ at the 5% level of significance, by Tukey's HSD. Each is a mean ± sd of 3 replications.
'Honeycrisp' apples were conditioned 7 days at 10 C.

Table 6. Fruit disorder incidence after five months of cold storage at 0.5 °C in ME-grown 'MN80' fruit harvested on 24 Sept., 8 Oct., and 12 Oct. 2019 and four months of cold storage at 0.5 °C or 4.0 °C in ME-grown 'MN80' fruit harvested on 24 Sept., 8 Oct., and 12 Oct. 2021. All fruit were stored in ME and data from both storage temperatures were pooled for analysis..

Harvest	Internal browning (%)		Soft scald (%)	
	2019	2021	2019	2021
1	0.0 ± 0.0 b[z]	11.4 ± 9.2	0.0 ± 0.0 c	0.0
2	1.8 ± 4.0 b	3.3 ± 3.3	22.7 ± 10.0 b	0.0
3	61.9 ± 17.5 a	--	55.8 ± 12.6 a	--

[z] Means within columns followed by common letters do not differ at the 5% level of significance, by Tukey's HSD. Each is a mean ± sd of three replications. Data were arcsine transformed for analysis, but actual means are presented.

ence on quality, so data for both temperatures were pooled (Table 5). 'MN80' had higher SSC than 'Cortland' or 'Honeycrisp' at 1 and 7 days. 'Honeycrisp' fruit had the lowest SSC, at the low end for this cultivar, but ME-grown fruit typically have SSCs of 11-14% at harvest, depending on year and crop load (Moran et al., 2020). Firmness was greatest in 'MN80' and lowest in 'Cortland' at both 1 and 7 days. Firmness was lower with the second harvest compared with the first for 'Honeycrisp' and 'MN80'. Peel color was greater for 'Honeycrisp' and 'MN80' than for 'Cortland' with no difference due to harvest date. 'Cortland' color was lower with the second harvest due to trees being previously spot picked by the grower taking the more highly colored fruit.

Internal browning and soft scald for 'MN80' fruit occurred with later harvest date and were severe with the third harvest (Table 6) in 2019. In 2021, storage temperature had no effect on disorders of 'MN80' fruit, so data from both were pooled. Internal browning occurred again in 2021 for fruit stored in ME, and with greater incidence for the first harvest compared with the second. No soft scald occurred in 'MN80' fruit in 2021, but 'Honeycrisp' fruit from the second harvest stored at 0.5 °C had soft scald (9.8 ± 3.4%). Bitter pit occurred with both harvests of 'Honeycrisp' fruit (1.9 ± 3.0%) and for 'Cortland' fruit from the first harvest (3.9 ± 3.3%). No bitter pit occurred in 'MN80' fruit. At the warmer storage temperature, 'Cortland' fruit developed senescence (10.9 ± 4.0%). Superficial scald did not occur in 'MN80' or 'Honeycrisp' fruit, but a very low incidence (<1%) occurred in 'Cortland' fruit. No disorders were detected for 'Cortland', 'Honeycrisp', or 'MN80' (ME- or WI-grown) fruit stored in MN at either 0-1 or 4-5 °C. Peel greasiness developed in 'MN80' fruit in 2021, but was not quantified.

The internal browning disorder observed in 'MN80' fruit resembled the diffuse flesh browning that occurs in 'Cripps Pink' and 'Honeycrisp' fruit (James and Jobling, 2009; Tong et al., 2016). 'MN80' fruit internal browning occurred primarily in the cortex. Internal browning in 'MN80' was more severe with later harvest in one year but not the next, when maturity was advanced at both harvest dates. Cold storage of 'MN80' fruit may therefore require timely harvest management.

Sensory evaluations. Participants rated the 'Honeycrisp' and ME-grown 'MN80' apples highest for overall liking, texture, crispness, juiciness, and flavor, followed by the WI-grown 'MN80', while 'Cortland' was rated lowest (Table 7) in Oct., a few weeks after harvest. Participants disliked the texture of 'Cortland' fruit so much that the fruit received a negative texture liking mean score. Participants liked the appearance and sweetness of 'Honeycrisp' fruit more than that of the other two cultivars. Overall, 'MN80' fruit compared well to that of 'Honeycrisp' and 'Cortland' at harvest, although growing location affected the degree to which 'MN80' fruit compared favorably to that of 'Honeycrisp'.

For the stored fruit, the only factor that affected any rating was type of apple (cultivar and source, $P < 0.001$). Storage temperature had no effect on any sensory ratings. Sensory participants rated ME-grown 'MN80' highest for overall liking, flavor liking, and texture liking (Table 8). It was also judged sweeter and crisper than the other apple cultivars. Most of the attributes of the stored ME-grown 'MN80' were not different from that of newly-harvested ME-grown 'MN80'. Sweetness and sourness of stored ME-grown 'MN80' increased and decreased, respectively, in comparison with its newly-harvested counterpart. Attributes of stored WI-grown 'MN80' were similar to that of the newly-harvested WI-grown 'MN80'. These data suggest that sensory attributes of 'MN80' fruit remain stable during storage. In contrast, attributes of 'Honeycrisp' and 'Cortland' fruit were judged less favorably between harvest and after storage. Stored 'Honeycrisp' fruit had lower overall

Table 7. Mean (N = 117) ratings given to each of the four cultivars for overall liking, aroma liking,texture liking, flavor liking, crispness, juiciness, sweetness, and sourness in Oct. 2021 for freshly-harvested fruit by panelists in MN. Liking ratings were made on 200-point labeled affective magnitude scales with "Greatest Imaginable Dislike" = -100, "Greatest Imaginable Like" = 100 and the midpoint "neutral" = 0. Intensity ratings were made on a modified 51-point magnitude scale from no intensity to 51 = extreme intensity.

	Cultivar and Source			
Attribute	MN80 - WI	MN80 - ME	Honeycrisp - ME	Cortland - ME
Overall liking	36b [z]	49 a	53 a	12 c
Appearance liking	44 b	38 b	60 a	39 b
Texture liking	46 b	58 a	60 a	-6 c
Flavor liking	29 b	44 a	48 a	20 b
Crispness	26 b	34 a	35 a	7 c
Juiciness	27 b	31 a	31 a	21 c
Sweetness	21 b	21 b	24 a	17 c
Sourness	7 b	13 a	11 a	13 a

[z] Mean intensities within columns followed by common letters do not differ at the 5% level of significance, by Tukey's HSD.

liking, appearance liking, texture liking, flavor, crispness, and sweetness scores, relative to 'MN80' fruit, than newly-harvested fruit. This may be due in part to the relatively late harvest date of 'Honeycrisp' fruit. Stored 'Cortland' was the least liked apple overall. It was rated as the least liked for flavor and texture, and the least juicy, crisp, and sweet of all the apples. These data suggest that, at least for four to five months in normal atmospheric conditions after harvest, 'MN80' fruit should store and rate with consumers as well as 'Honeycrisp' fruit, so worthwhile for small-scale orchards.

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Table 8. Mean ratings (N = 96) given to each of the four apple types after four months of storage for overall liking, appearance liking, texture liking, flavor liking, crispness, juiciness, sweetness, and sourness by panelists in MN in Jan. 2022. Storage temperature had no effect on ratings, so ratings for apples stored at 0-1 °C and 4-5 °C were aggregated. Liking ratings were made on 200-point labeled affective magnitude scales with the left most end labeled "Greatest Imaginable Dislike" = -100, the right most end labeled "Greatest Imaginable Like" = 100 and the midpoint "neutral" = 0. Intensity ratings were made on modified 51-point labeled magnitude scales with the left most ends = none and the right most ends = extreme.

	Cultivar and Source			
Attribute	MN80 - WI	MN80 - ME	Honeycrisp - ME	Cortland - ME
Overall liking	31 b[z]	48 a	29 b	-24 c
Appearance liking	41 b	42 a	49 a	35 b
Texture liking	42 b	54 a	42 b	-44 c
Flavor liking	24 b	43 a	20 b	-8 c
Crispness	27 b	32 a	28 b	2 c
Juiciness	25 b	28 a	27 ab	14 c
Sweetness	20 b	23 a	17 b	12 c
Sourness	6 c	8 bc	11 a	10 ab

[z] Mean intensities within columns followed by common letters do not differ at the 5% level of significance, by Tukey's HSD.

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