COMPARING APPLES TO APPLES

Single-varietal hard apple cider testing

Prepared by the UW-Madison Center for Integrated Agricultural Systems

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TABLE OF CONTENTS

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EXECUTIVE SUMMARY

Establishing an apple orchard is a major financial investment. Growers decide which varieties to grow long before they have fruit ready for sale. While much is known about consumer preferences for varieties of apples for fresh use, this is not the case for hard cider apple varieties. Do consumers want sweet hard ciders? Floral notes? The complex flavors and aromas resulting from high levels of tannins? The goal of the Apples to Apples Project was to help hard cider growers—and makers—select apple varieties for a high-quality, artisanal product. To accomplish this, researchers compared the results of laboratory analysis and tastings of single-varietal ciders to identify desirable flavor characteristics.

Growers from four orchards near Madison, Wisconsin provided 41 varieties of hard cider apples in the fall of 2017 for testing. Staff at the UW-Madison Food Science Fermentation Sciences Program pressed each variety separately and produced about a gallon of cider from each variety. Each single-varietal hard cider was tested in two ways to determine taste characteristics: first in the laboratory and then by at least one panel of tasters at four separate tasting events held during the winter of 2017-18.

Laboratory analysis included pH, titratable acidity (TA), degrees Brix (°Brix) and phenolics. Most of the varieties fell within ideal ranges for pH and °Brix; fewer fell within ideal ranges for TA and phenolics. Cider makers commonly blend apple juices to attain a product in the ideal range. Apples that are outside of the ideal range are useful in adjusting a blend.

The initial and most comprehensive tasting provided baseline data on all varieties. The subsequent three tastings aimed to collect more specific data on flavor qualities, allowing comparison of flavors and preferences across different tastings. The tasting results were analyzed on four flavor components: acidity, sweetness, astringency and bitterness. The researchers also collected qualitative data on cider flavor, mouthfeel and strength. Different tastings yielded different high and low overall ratings.

Photo: Eleanor Voigt

Researchers transported several varieties of apples from the orchards to the laboratory.

It is easier and less expensive to analyze cider chemistry in the laboratory than to gather flavor and other sensory data. Furthermore, taste can vary from year to year, orchard to orchard, and taster to taster. To address this, project researchers used a multivariate analysis to explore how closely laboratory measure-

ments of variables such as pH and phenolics reflected the tasters' perceptions of characteristics such as acidity and bitterness.

As expected, phenolics were closely related to tasters' perceptions of astringency and bitterness. °Brix was significantly correlated with bitterness and perceived strength (alcohol). Titratable acidity (TA) and pH were equally correlated with perceived acidity. The perception of acidity in the tasting trials traced closely to the laboratory results for all but one apple variety.

The ciders rated highest overall by the tasting panels were predominantly perceived as sweet or balanced in flavor, with preferences leaning towards higher perceived sweetness and acidity. The highest-rated ciders were negatively correlated with phenolics, which were closely associated with bitter and astringent flavors. The lowest-rated ciders had high levels of TA, °Brix and/or phenolics.

To more accurately describe the chemical components and taste perception of hard ciders, multiple years of data collected from more locations are needed. Long-term trials in which the same apple varieties are gathered from the same farms, and brewed and tested over multiple years, would improve the accuracy of results. A larger, more segmented taste test is also necessary to understand consumer preferences. In a larger study, researchers may also gain a better understanding of how soil types, microclimates, weather or production practices might contribute to terroir, also known as "taste of place."

APPLES TO APPLES

Introduction

Hard cider apple growers and makers face complex decisions about which apple varieties to select, graft and blend. Do consumers want sweet hard ciders? Floral notes? The complex flavors and aromas resulting from high levels of tannins? To help hard cider growers and makers select apple varieties for a high-quality, artisanal product, the Apples to Apples Project combined grower knowledge with laboratory analysis and tastings to identify desirable flavor characteristics in hard apple ciders. This project advanced an understanding of consumer flavor preferences in hard ciders and the apple varieties that can provide those qualities. It also showed how laboratory testing results may predict certain flavors.

This project focused on apples that grow well in the North Central Region of the United States. This region is comprised of 13 states[1] and home to small-scale cideries that source apples from local or regional orchards.[2]

Hard cider makers mix juice from multiple apple varieties to attain desired characteristics. While hard cider can be made from the dessert apples used for unfermented cider, hard-cider-specific apples can provide a more complex and desirable flavor and mouthfeel. Apples from these varieties are higher in tannins and sugar than dessert apples, creating more complex flavors in finished ciders. Cider makers can blend juice from hard-cider-specific varieties with juice from dessert apples to sweeten and balance the final product.

Growers and cider crafters desire more information about hard cider apple qualities. In this study, growers identified regional apple varieties that show horticultural promise and good cider flavor potential, and provided apples from those varieties for laboratory and tasting research on flavor characteristics. The researchers sought to understand each unique apple variety, and thus brewed and tested 41 single-varietal hard ciders. This report documents the results of the laboratory analyses and four cider tastings with tasters representing different areas of expertise.

The Center for Integrated Agricultural Systems (CIAS) conducted this research in collaboration with farmers, cider makers and researchers from the University of Wisconsin-Madison College of Agricultural and Life Sciences. Four local cider apple growers and crafters were part of the research team:

[1]States in the North Central Region are Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota and Wisconsin.

[2]Matt Raboin, "Hard Cider in the North Central Region: Industry Survey Findings." (Madison, WI: UW-Madison Center for Integrated Agricultural Systems, 2017), accessed 3/21/19; available from https://www.cias.wisc.edu/wp-content/uploads/2017/07/cideerstudy071817web.pdf.

Photo: Nicholas Smith

Apple aesthetics are not important to cider makers.

Albion Prairie Farm, Brix Cider, The Cider Farm and Cider House of Wisconsin (see Appendix A). The UW-Madison research team included members of the Department of Horticulture and Fermentation Sciences Program in the Department of Food Science, in addition to CIAS staff.

Hard cider is a value-added product that can be processed and marketed year-round, with a longer shelf life than fresh apples. Apple production for hard cider has the potential to decrease pesticide use, as apple aesthetics are not critical, so fewer pesticides are needed to control insects and diseases that damage fruit. Hard cider production also has the potential to create a high-value market for imperfect dessert apples.[3] Because apple trees are perennials, orchards hold soil in place and protect against erosion, especially during heavy rainfall events, and can be part of an environmentally sustainable landscape. Planting a perennial crop such as apple trees, however, is a significant, long-term investment. Research on the taste characteristics of cider apple varieties may help growers select those that have the potential to attract consumer demand.

Historically, hard cider was a popular beverage among colonists and settlers in the U.S. in the 18th and 19th centuries. Cider production declined significantly in the mid-1800s due to a number of factors, including the temperance movement and the influx of German immigrants with beer-making skills. Beer consumption became more widespread as breweries took advantage of technological advances including improved rail networks and automated bottling plants.[4]

Today, hard cider is experiencing a revival. Hard cider production increased annually by 50 percent between 2009 and 2014.[5] Off-premise hard cider sales experienced double-digit growth from 2011-2014, peaking at $528 million in 2015. Sales declined in 2016 and 2017, but rebounded in 2018.[6]

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[3]Carol Miles, et al., "Evaluating Apple Varieties for Hard Cider Production" (Pullman, WA: Washington State University, 2013), accessed 8/3/18; available from http://csanr.wsu.edu/wp-content/uploads/2012/06/id96-Miles.pdf.

[4]Alfred Warner, "The Evolution of the American Brewing Industry," *Journal of Business Case Studies* 6, no. 6 (Nov/Dec 2010), accessed 3/21/19; available from https://clutejournals.com/index.php/JBCS/article/download/257/247.

[5]Florence Becot, Terence Bradshaw, and David Conner, "Apple market expansion through value-added hard cider production: Current production and prospects in Vermont," *HortTechnology* 26, no.2 (2010): 220-229, accessed 3/21/19; available from https://journals.ashs.org/horttech/view/journals/horttech/26/2/article-p220.xml.

[6]Danny Brager. "The Cider Rebound." Nielsen presentation at 2019 CiderCon, 2/7/2019, accessed 6/19/19; available from https://ciderassociation.org/wp-content/uploads/2019/02/Nielsen-Presn-at-CiderCon-2019_2-7-2019.pdf.

Regional and local hard cider brands make up almost a third of all ciders sold and are leading this growth. Craft and local ciders held a 20 percent share of the total cider market in the first 13 weeks of 2017, up from 7.8 percent in 2014. The dollar amount of sales of the craft/local cider segment steadily increased each year from 2012 to 2016, and 65 percent of cider consumers prefer to purchase from local cideries.[7] From 2014-2018, the regional/local market grew by 23 percent, compared to a four percent growth rate in national brands.[8] Off-premise sales of regional and local cider brands were up 26 percent in the first quarter of 2018, compared to two percent growth for national brands.[9] Nearly 58 percent of cider drinkers are 21 to 34 years old, and do not skew toward one gender, unlike wine, beer and spirits.[10]

Photo: Matt Raboin

In a survey, cider apple growers and makers indicated a need for research on varieties and flavor.

This study follows up on an earlier CIAS survey of cider growers across the North Central United States, the majority being small startup companies. The surveyed cider makers highly ranked the need for research and new information. They also identified research topics of interest, including juice and cider properties of specific apple varieties, chemistry and microbiology of cider, and consumer taste preferences. They rated the cosmetic appearance of apples as "least important" in choosing which fruit to buy and use. Respondents also sourced over 90 percent of their apples locally or regionally.[11] These survey results set the stage for the Apples to Apples Project.

Materials and methods

Apple varieties

Growers provided 41 varieties of hard cider apples in the fall of 2017 (see Appendix B for a list of varieties and sources). A bushel of each variety was sourced from four orchards near Madison, Wisconsin: Albion Prairie Farm, Brix Cider, The Cider Farm and Cider House of Wisconsin. The growers selected varieties for desirable flavor components and sustainable production potential, harvested ripe apples, and stored them until CIAS staff transported

[7]Danny Brager and Matt Crompton. "Cider Trends in the US: How to Increase Your Odds of Success by Evaluating Marketplace Dynamics," Nielsen presentation to the US Association of Cider Makers annual meeting, Chicago, IL, April 5, 2017, accessed 3/21/19; available from https://ciderassociation.org/cider-trends-in-the-u-s/.

[8]Brager, 2019.

[9]Tara Nurin. "Hard Cider Sales Rebound After Two Years of Declines," *Forbes,* May 31, 2018, accessed 10/15/18; available from https://www.forbes.com/sites/taranurin/2018/05/31/hard-cider-sales-rebound-after-two-years-of-declines/#3889e12d302e.

[10]Brager, 2019.

[11]Raboin, 2017.

them to the Food Science Fermentation Sciences laboratory at the University of Wisconsin-Madison. The apples were refrigerated until they were pressed.

The growers in this study noted that keeping track of apple tree varieties can be difficult. For example, scion wood can be mislabeled. As a result, the growers who supplied what they believed to be Ellis Bitter and Oaken Pin apples used in this study now consider these trees in their orchards to be unknown varieties (referred to as Unknown 1 and Unknown 2).

Cider production

Staff at the Fermentation Sciences Program pressed each variety separately and placed each batch into coolers to settle. The juice was then siphoned into clean containers ("racked off the lees"). SafCider (Fermentis) yeast (0.3 g/l) rehydrated in 20 times its weight of water and 0.3 g/l Startup (a yeast rehydration nutrient blend) was added, along with 0.4 g/l of Superfood (a yeast nutritional product) to feed the yeast. The juice was fermented at 60 degrees F for two weeks and then chilled to 35 degrees F to settle the yeast. The cider was then siphoned off of the yeast. Forty ppm sulfur dioxide was added as a preservative, and the cider was bottled and stored at 41 degrees F. About a gallon of cider was produced from each variety.

Each single-varietal hard cider was tested in two ways to determine taste characteristics: The first set of tests were performed in the laboratory and then each cider was sampled by at least one panel of tasters.

Laboratory analysis

Before fermentation, the apple juice was analyzed for pH, titratable acidity (TA, g/L malic acid equivalent, or MAE), and degrees Brix (°Brix, g sugar/100g solution). pH was measured on a Thermo Scientific Orion Star A111 pH meter. The cider was titrated with 0.1 N sodium hydroxide (NaOH) to pH 8.2, and °Brix was measured with handheld refractometer. After fermentation, the laboratory tested the cider for total phenolics (ppm gallic acid equivalent, or GAE) using the Folin-Ciocalteau reagent. Alcohol levels were not directly tested, but the perception of alcohol was identified in subsequent sensory tastings. The figures in Appendix C compare laboratory results for each variety with ideal ranges for each measurement.

Tastings

The project team conducted four cider tastings with self-selected tasters representing different areas of expertise—culinary arts, retail sales, farming and cider making—as well as consumers. Since tasters had volunteered, they presumably like or were curious about cider and were therefore at least somewhat representative of cider consumers. Furthermore, rapid sensory evaluation methods rely on the participation of chefs, culinary professionals

and consumers rather than trained sensory panelists.[12] Each of the 41 single-varietal ciders was tasted at one or more of these tasting events by at least six people. Each tasting included a commercially available, blended cider as a flavor standard, or check, reference point for desirable flavor (Classic Dry or Tremlett's commercial). The check cider reflected a balanced flavor profile; its identity was not revealed to the tasters. Ciders were assigned a randomized three-letter code so that tasters wouldn't be influenced by the varietal names. See Table 1 and the Tasting results section on page 7 for detailed information on each of the tastings, and Appendix D for details on the statistical analysis of the tasting data.

Table 1. Tasting event information

Date	Number of tasters	Description of tasters	Cider varieties tasted	Purpose of tasting
12/12/2017	20	Dawson Lab and research team, including cider producers	All 41 plus Classic Dry commercial check, 12-18 per taster, in an incomplete block design	Baseline testing of all varieties.
1/15/2018	11	Farmers and chefs of the Seed to Kitchen Collaborative	12 total, all tasted by each taster: Bergere, Cap of Liberty, Chisel Jersey, Classic Dry commercial check, Dabinett, Kandil Sinap, Liberty CH, Unknown 1, Unknown 2, Royal Russet, Swaar, Tremlett's Bitter	Flavor traits of, and preferences for, varieties representing different levels of astringency, acidity, bitterness, and sweetness.
1/22/2018	19	Farmers and other attendees at the Wisconsin Fresh Fruit and Vegetable Conference	8 total, all tasted by each taster: Dabinett, Golden Russet, Liberty CF, Old Nonpariel, Red Delicious, Somerset Redstreak, Thornberry, Tremlett's commercial check	Flavor traits of, and preferences for, varieties exhibiting balance between sweetness and acidity, and bitterness and astringency
2/14/2018	17	Willy Street Co-op employees	8 total, all tasted by each taster: Bergere, Brown's Apple, Cap of Liberty, Classic Dry check, Driftless Cider, Liberty CH, Unknown 1, Unknown 2	Flavor traits of, and preferences for, varieties representing the more extreme, rather than balanced, taste profiles

[12]Michael Frøst, Davide Giacaone and Kristen Rasmussen, "Alternative methods of sensory testing: working with chefs, culinary professionals and brew masters," in *Rapid Sensory Profiling Techniques and Related Methods*, Julien Delarue, Ben Lawlor, Michel Rogeaux, eds., 2015, Cambridge: Woodhead Publishing, accessed 10/29/19; available from doi: 10.1533/9781782422587.3.363.

Photo: Michelle Miller

The UW-Madison Fermentation Sciences Program created ciders from each of the 41 apple varieties.

Laboratory analysis results

pH

pH measures relative acidity or alkalinity of a substance on a numeric scale, with a pH of 7 being neutral and smaller numbers being more acidic. pH contributes to microbial stability and enzymatic reactions causing fermentation. Lower pH decreases the likelihood of microbial infection and spoilage.[13]

The pH of the tested juices ranged from 2.99 to 4.4. The ideal pH range for juice used in cider making is about 3.2 to 3.8.[14] Cider makers commonly blend apple juices to attain a product in the ideal pH range. Apples that are outside of the ideal range are useful in adjusting a blend.

Titratable acidity

Titratable acidity (TA) is a measure of acid concentration. This is not the same as pH, due to the buffering capacity of organic acids within the cider.[15] As TA values go up, pH values go down, and vice-versa.[16] Like pH, TA affects the storage and likelihood of spoilage of finished ciders. TA is especially helpful in predicting sour flavor, as it is generally the better measure of perceived acidity.[17]

The TA of the tested juices ranged from 1.6 g/L MAE to 14.5 g/L MAE. The ideal range for juice used in cider making is much narrower, at about 4.5 to 7.5 g/L MAE.[18] Again, juice from apples that are outside of the ideal range can be useful in adjusting a blend.

Degrees Brix

Degrees Brix (°Brix) is a measurement of the sugar content of a liquid. Apple juices used for hard cider traditionally have high levels of °Brix. Because fermentation turns sugar into alcohol, higher levels of °Brix in juice result in stronger, but not necessarily sweeter, ciders. °Brix in juice is used to estimate

[13]North Carolina Craft Beverage Regional Exchange Group, "Cider Basics," (Boone, NC: Appalachian State Fermentation Sciences, 2015), accessed 3/25/19; available from https://wine.appstate.edu/sites/wine.appstate.edu/files/Cider_Basics_REG_6-25-15.pdf.

[14]Andrew Lea, "The Science of Cidermaking, Part 3-Juicing and Fermenting," 1997, accessed 3/25/19; available at: http://www.cider.org.uk/part3.htm.

[15]North Carolina Craft Beverage Regional Exchange Group, 2015.

[16]Lea, 1997.

[17]Lea, 1997.

[18]Claude Jolicoeur, "Acidity and pH of Apple Juice," (Quebec, Canada, 2011), accessed 3/25/19; available from http://cjoliprsf.ca/Documents/Acidity-pH.pdf.

how much alcohol might be created during fermentation.

The °Brix range of tested juices was found to be between 10 to 18g sugar/100g solution. The ideal °Brix level for commercial hard cider is about 11 to 15g sugar/100g solution.[19] Cider makers may add sugar by back sweetening, where cider is treated to halt fermentation and then sweetened, or mix juice from different varieties to change the °Brix.

Photo: Michelle Miller

Tasters evaluated flavor and qualitative components for each cider sample.

Phenolics

Phenolics are natural compounds including anthocyanins and tannins that contribute bitterness, astringency, color, mouthfeel and aroma to finished hard ciders.[20] High-tannin apples are useful in adding flavor complexity to blends that contain mostly low-tannin dessert apples. Unlike pH, TA and °Brix, phenolics are measured after fermentation.

Hard cider apple varieties traditionally have high levels of phenolics; however, 32 of the single-varietal ciders in this study were low in phenolics, ranging from 361 to 3,021 ppm GAE. The ideal level of phenolics in hard cider is about 2,000 ppm GAE.[21] Levels of phenolics can be changed by mixing apple varieties or adding other sources of tannins.[22] The bitterness associated with excessive tannins can be addressed by back sweetening.

Tasting results

The initial and most comprehensive tasting in December 2017 provided baseline data on all varieties. The twenty participants, including growers from each of the four orchards, together tasted all 41 single-varietal ciders and a Classic Dry commercial check, with each taster sampling 12 or 18 varieties in sets of six. The tasting results were analyzed on four flavor components: acidity, sweetness, astringency and bitterness. None of the varieties could be

[19]Ben Calvi, "Basic Laboratory Analysis of Fruit for Cider Making," (Burlington, VT: University of Vermont, 2015), accessed 3/25/19; available from http://www.uvm.edu/~fruit/treefruit/tf_cider/CalviWLCider033015.pdf.

[20]Andrew Lea, "Phenolics in Cider Apples: What do they mean for us?," Presentation to Rocky Mountain Cider Association, April 2015, accessed 3/25/19; available from http://www.cider.org.uk/phenolics_in_cider_apples.pdf.

[21]Andrew Lea and John Piggot, eds., *Fermented Beverage Production*, 2nd edition, (Berlin: Springer Science + Business Media, LLC, 2003), first published by Kluwer Academic/Plenum Publishers.

[22]Ian Merwin, Ian, Sarah Valois, and Olga Padilla-Zakour. "Cider Apples and Cider-Making Techniques in Europe and North America." *Horticultural reviews* 34 (April 2008):365-415, accessed 3/25/10; available from https://www.researchgate.net/publication/263010717_Cider_Apples_and_Cider-Making_Techniques_in_Europe_and_North_America.

considered sweet by "eating apple" standards. The researchers also collected qualitative data on cider flavor, mouthfeel and strength. Results are detailed in Appendix E.

The tasters preferred ciders that were perceived as sweet or balanced between sweetness and acidity. Liberty, Kingston Black, Unknown 1, Tremlett's Bitter and Steele Red were the favorite varieties, in addition to the check cider. Liberty CH was the best overall, Old Nonpariel had the best mouthfeel and Cap of Liberty was the most intense. Four apple varieties had the highest perceived strength/alcoholic content: Golden Russet, Thornberry, Dabinett and Unknown 2. The least favorite varieties—Priscilla, Somerset Redstreak and Red Delicious—were perceived as bitter. Overall ratings are shown in Figure 1 on the facing page.

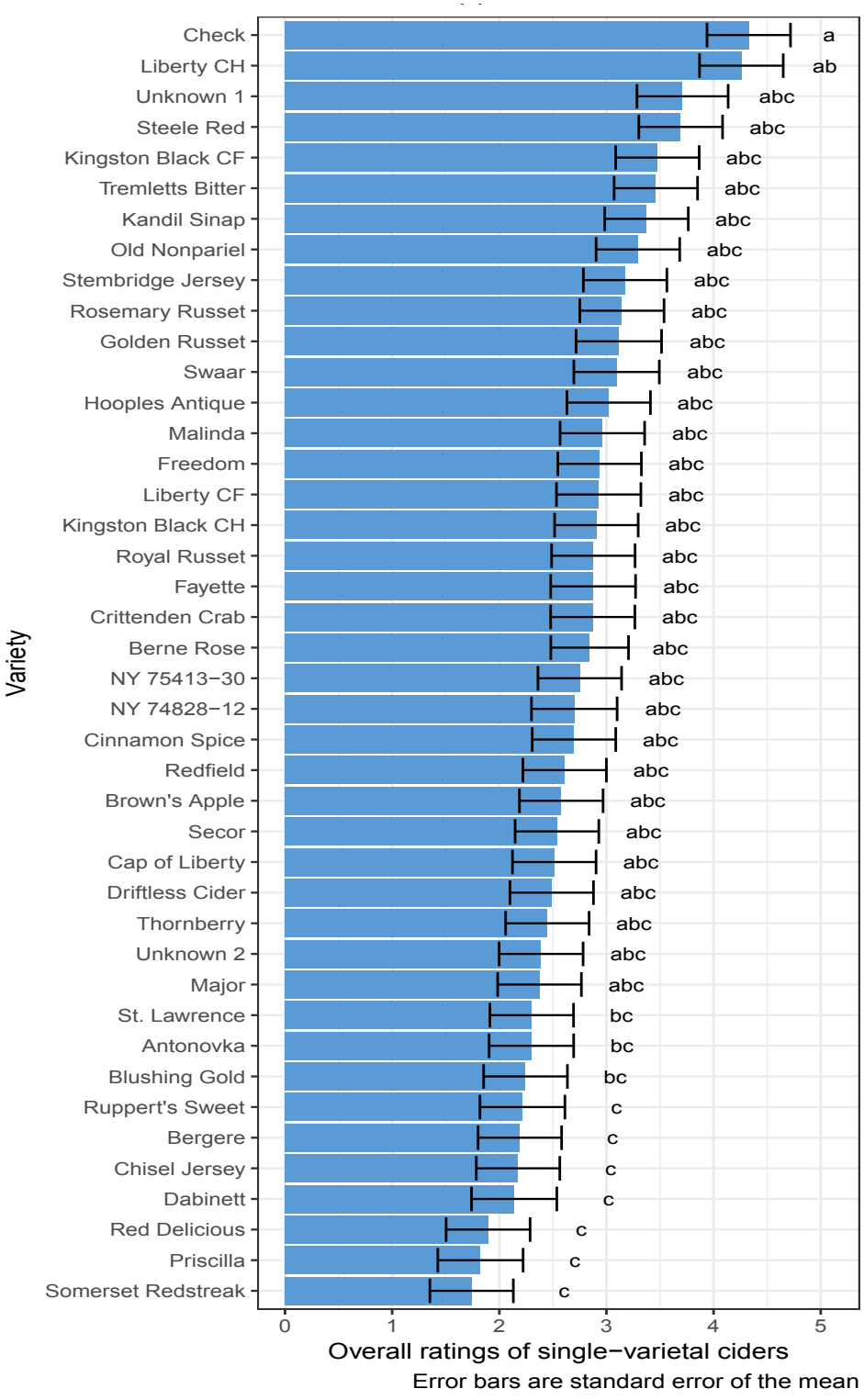
Different tastings yielded different high and low overall ratings. The Classic Dry commercial check, Liberty CH, Unknown 1 and Steele Red were the overall favorites in the first tasting. Classic Dry and Steele Red were mildly sweet and acid, and Liberty CH was high in sweetness. The lowest-rated ciders overall were Priscilla, Somerset Redstreak, and Red Delicious. As stated above, these were predominantly bitter.

The subsequent three tastings aimed to collect more specific data on flavor qualities, allowing comparison of flavors and preferences across different tastings.

The second tasting, held in January 2018, included chefs, fresh market vegetable growers and staff from the Seed to Kitchen Collaborative in the UW-Madison Horticulture Department. Eleven ciders were tasted, plus one check commercial cider. These ciders were chosen to represent different levels of the four main flavor components listed above. Tasters in the second round gravitated to the intense, acidic Cap of Liberty and the somewhat bitter Bergere. Least favorite were ciders made with less intense apples—Chisel Jersey and Dabinett—and the intense but very sweet Liberty CH. The results of this tasting differed somewhat from the overall taste preferences from the first event, indicating that this subset of tasters may have had unique flavor preferences. This is similar to results observed in vegetable variety tastings, where chefs prefer more complex and intense flavors than the general public.

The third tasting was held at the January 2018 Wisconsin Fresh Fruit and Vegetable Conference. Many of the tasters had an interest in growing apples, or were growing grapes and making wine. The eight varieties selected for this tasting exhibited a balance between sweet and acid, and bitter and astringent, and included a commercial Tremlett's rather than Classic Dry as the check cider. Liberty CF and the Tremlett's check were the favorite ciders at this tasting. The tasting panel rated Liberty CF as well balanced among these traits, while the Tremlett's check was rated as predominantly sweet.

Figure 1. Tasters' overall ratings of single-varietal ciders, first tasting event*



*The X axis is the overall tasting score where 0 = very bad and 5 = excellent. Note that the highest overall, Classic Dry, was a commercial check variety. Bars marked with the letter a are statistically different than those marked without an a, those marked with the letter b are statistically different than those marked without a b, and those marked with the letter c are statistically different from those without a c.

Photo: Ruth McNair

A grower gets some advice during a grafting workshop.

Dabinett and Somerset Redstreak had the lowest overall ratings. Their flavor profiles were both predominantly bitter.

The fourth and final tasting was held in February 2018, and engaged seventeen employees at the Willy Street Co-op in Madison, Wisconsin. The tasting panel included some of the store's hard cider buyers. For this tasting, the researchers chose eight varieties (including a commercial Classic Dry for the check cider) that represented the extremes of bitterness, astringency, sweetness and acidity, contrasting with the more balanced varieties used in the third tasting.

The highest-rated ciders overall for this tasting were the commercial check and Brown's Apple. The check cider had a high level of perceived sweetness, while the Brown's Apple was more balanced and slightly skewed towards sweetness and acidity. Those with the lowest overall ratings were Unknown 2 and Driftless Cider. They both exhibited high levels of bitterness, and Driftless Cider also exhibited astringency. Note that while Liberty CH had the highest overall rating in the first tasting, it was not the favorite in this smaller trial.

The results of the four single-varietal tastings were used to identify promising varieties for grower outreach through a grafting workshop held on April 21, 2018 (see Appendix F). Results of these tastings, along with pictures, horticultural notes and flavor results, are in Appendix G.

Comparing laboratory and tasting data

Chemical compounds interact in complex ways to create flavor. That said, it is easier and less expensive to analyze cider chemistry in the laboratory than to gather flavor and other sensory data. Furthermore, taste can vary from year to year, orchard to orchard, and taster to taster. To address this, project researchers compared the laboratory and tasting data to see how laboratory measurements of variables such as pH and phenolics correlate to taste characteristics such as acidity and bitterness.

The researchers used Multiple Factor Analysis (MFA) to explore how closely the laboratory data reflected the tasters' perceptions (Figure 2). MFA is an analytical tool for comparing different types of data when there are many variables in the mix. The axes in Figures 2 and 3 on pages 12 and 13 are not representations of two discrete variables, typical of Cartesian graphs. This analysis involves multiple variables, and MFA condenses them to two dimen-

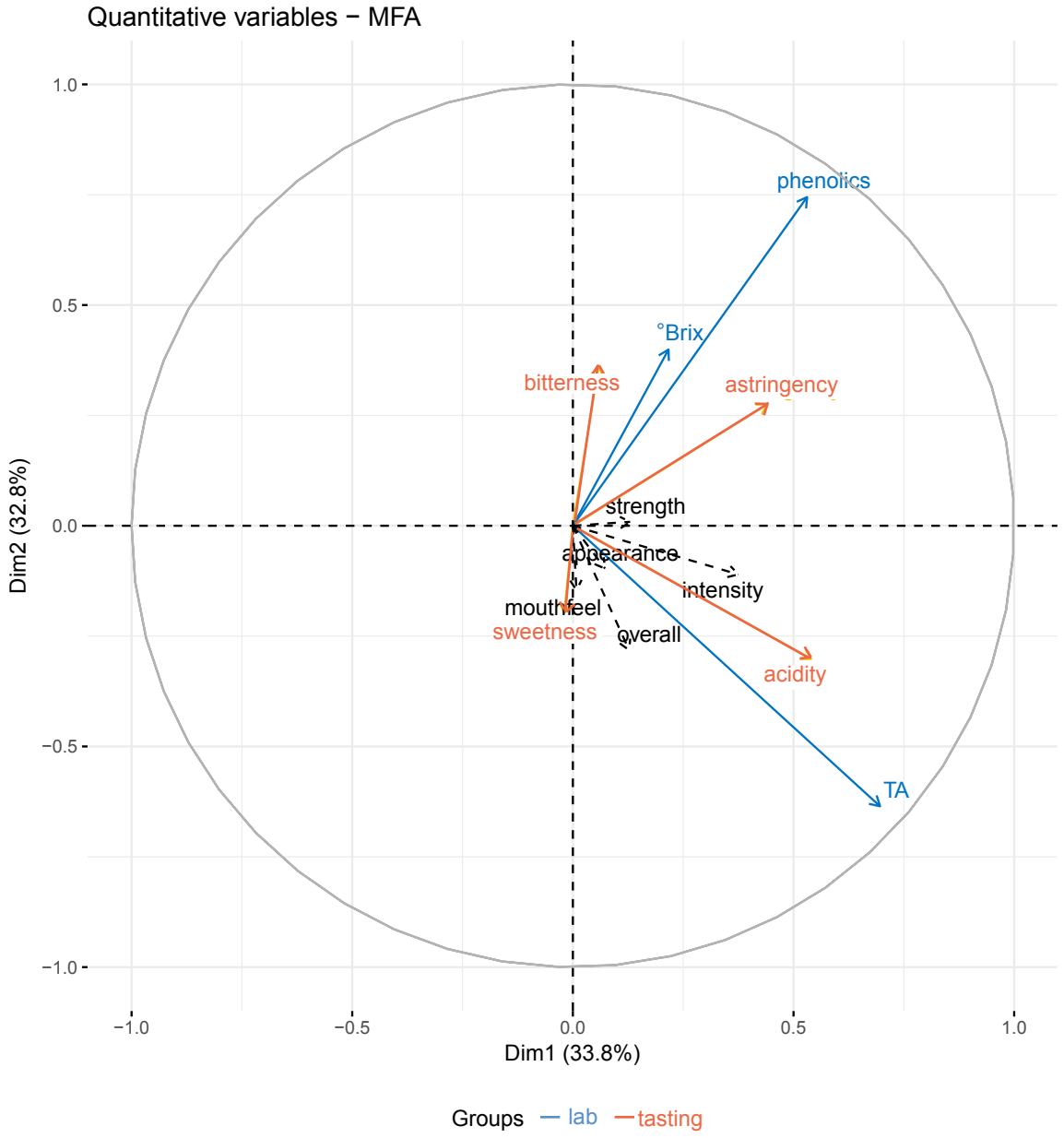
sions, with each dimension reflecting dominant variables. Figures 4 and 5 on page 14 show how the different laboratory and tasting variables contribute to each dimension.

Figure 2 shows both the correlation and the importance of the variables. Laboratory-measured variables are blue, and sensory variables are orange. The direction of each arrow shows the direction in which that trait increases. If you mentally overlay Figures 2 and 3, apple varieties found in the top right are more phenolic, and in the bottom right are more acidic. The angles between the arrows show the correlation among the variables. The length of each arrow corresponds to the importance of that factor in explaining differences among varieties in our data set. For example, phenolics and TA are longer arrows and therefore contribute more to overall variation than °Brix. Phenolics and TA are at a 90 degree angle to each other, meaning that they are not correlated in this dataset. °Brix, however, is highly correlated with phenolics, since the arrows point in similar directions.

The variables shown in black in Figure 2—strength, appearance, mouthfeel and intensity—were not used in this analysis because they do not represent individual flavor components, but are plotted here to show their correlation with other variables in the data set. Mouthfeel is highly correlated with perceived sweetness, and overall flavor ratings were positively correlated with sweetness and acidity. Overall flavor was negatively correlated with bitterness, and not correlated with astringency.

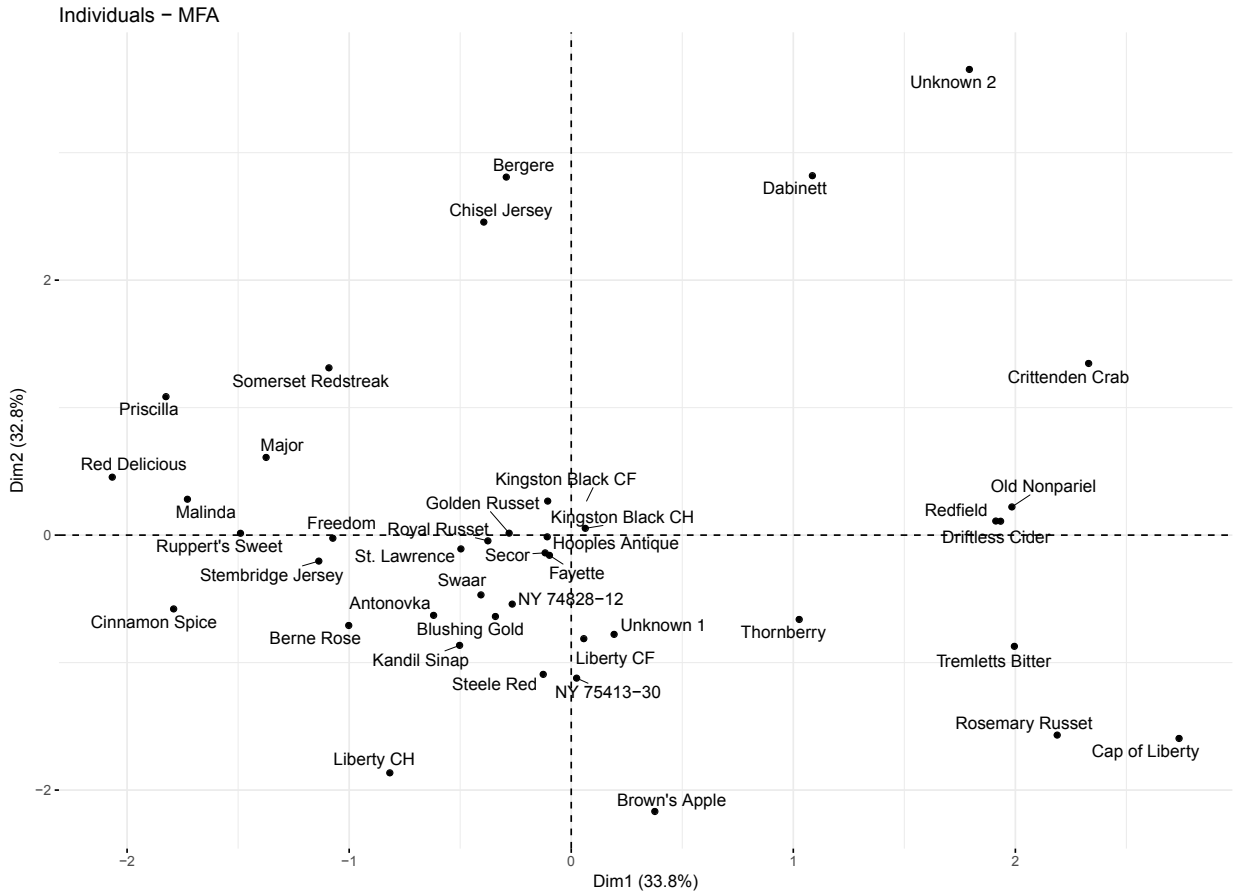
Figure 3 shows variation among the single varietal ciders. The position of each variety shows its relationship to other varieties and the variables on the first graph. For example, Unknown 2 is the variety with the highest level of phenolics, followed by Dabinett. Both were also perceived as the most bitter, as were Bergere and Chisel Jersey. The varieties around the perimeter of the graph show more pronounced differences, while the varieties clustered towards the center exhibit a more balanced contribution of all variables. The varieties on the perimeter might be good candidates for adding specific flavor components to a blend, while the ones in the center may be better candidates for a base apple that is not too pronounced in any one of the flavor components.

Figure 2. Relationship of measured laboratory characteristics of apple juices and flavor components in the resulting hard ciders. Several non-flavor components—appearance, intensity, mouthfeel, strength, and overall flavor (in black)—are plotted for comparison.



Laboratory-measured variables are shown in blue, and sensory variables are shown in orange. The direction of each arrow shows the direction in which that trait increases. The angles between the arrows show the correlation among the variables. The length of the arrow corresponds to the importance of that factor in explaining differences among varieties, with longer arrows representing a higher contribution to variation. The dashed horizontal and vertical lines represent the two dimensions resulting from the Multiple Factor Analysis.

Figure 3. Relationship of single-varietal ciders in terms of the laboratory and flavor components plotted in Figure 2.



On the figure above, the position of each variety shows its relationship to other varieties and the variables on the first graph. For example, if you mentally overlay Figures 2 and 3, apple varieties found in the top right are more phenolic, and in the bottom right are more acidic. Varieties around the perimeter of the graph show more pronounced differences, while those clustered in the center show a more balanced contribution of all variables. The dashed horizontal and vertical lines represent the two dimensions resulting from the Multiple Factor Analysis.

Figure 4. Variables that contribute to Dimension 1 (vertical axis)

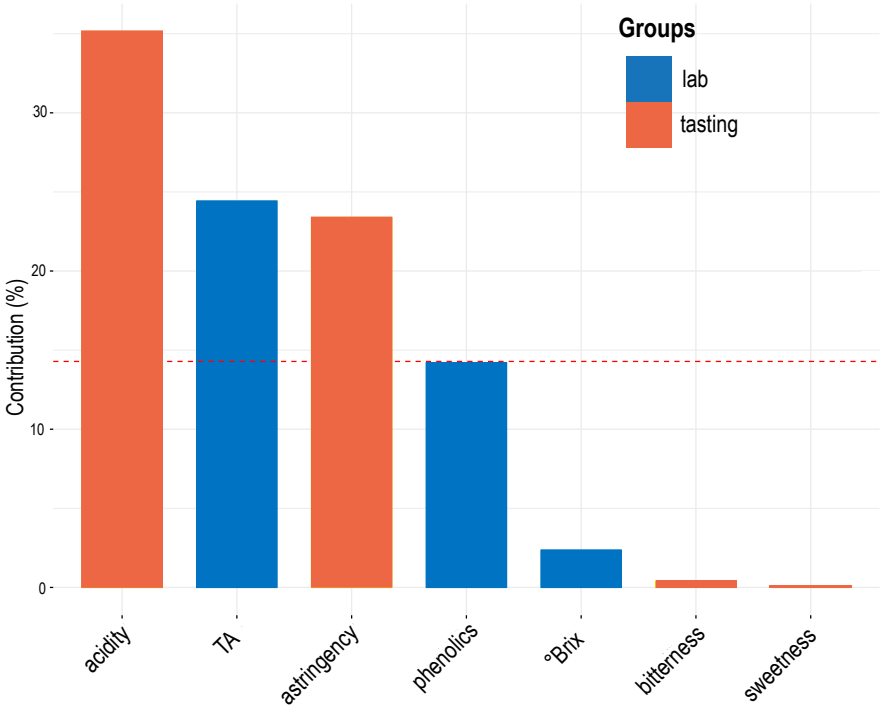
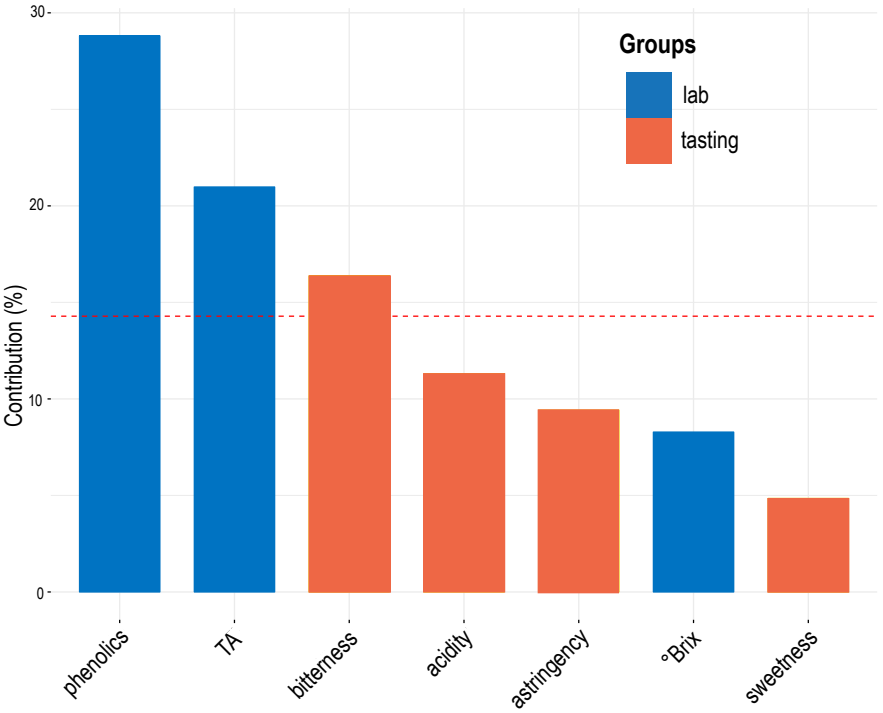


Figure 5. Variables that contribute to Dimension 2 (horizontal axis)



The contribution of each of the laboratory variables and the flavor components are shown in Figure 4 (dimension 1) and Figure 5 (dimension 2).

Table 2 below shows correlation between the laboratory and tasting data. As expected, the researchers found phenolics to be closely related to perception of astringency and bitterness, with a correlation of 0.70 ($p < 0.001$) and 0.45 ($p < 0.01$), respectively. It is interesting that °Brix is also correlated to these variables. °Brix was significantly correlated with bitterness at 0.35 ($p < 0.05$) and perceived strength (alcohol) at 0.37 ($p < 0.01$). One limitation of this research is that none of the laboratory variables, including the raw juice °Brix, correlate to the sweetness of the finished cider.

Titratable acidity (TA) and pH are both measures of acidity. TA is generally considered the better measure of perceived acidity as it mimics some of the reactions that happen in the mouth when organic acids come into contact with saliva, which is less acidic. However, in this dataset, these two measures were equally correlated with perceived acidity. The correlation between TA and perceived acidity was 0.79 ($p < 0.001$), and between pH and perceived acidity was -0.74 ($p < 0.001$). The negative correlation was due to the measurement scale, as lower pH values are more acid.

The perception of acidity in the tasting trials was closely related to the laboratory results. The only exception was for the variety Dabinett, which was perceived as tasting more acidic than laboratory measurements would have predicted. This could be due to its high phenolic content, and this result might serve as an example of how interactions between °Brix, phenolics and TA create flavor.

Table 2. Correlations among variables for tasting and laboratory data

	sweetness	acidity	astringency	bitterness	intensity	strength	appearance	mouthfeel	overall	°Brix	pH	TA	phenolics
sweetness	1	0.02	-0.34	-0.02	0.14	0.41	0.35	0.56	0.45	0.19	-0.17	0.22	-0.27
acidity	0.9150	1	0.36	-0.19	0.70	0.25	0.19	0.13	0.29	-0.05	-0.74	0.79	0.08
astringency	0.0291	0.0198	1	0.36	0.44	0.10	-0.01	-0.11	-0.08	0.12	-0.02	0.21	0.70
bitterness	0.8939	0.2224	0.0189	1	0.27	0.21	-0.03	0.10	0.03	0.35	0.46	-0.27	0.45
intensity	0.3929	0.0000	0.0032	0.0854	1	0.44	0.28	0.27	0.32	0.12	-0.43	0.66	0.23
strength	0.0067	0.1138	0.5254	0.1748	0.0037	1	0.22	0.39	0.33	0.37	0.01	0.18	0.14
appearance	0.0222	0.2345	0.9663	0.8558	0.0728	0.1642	1	0.34	0.30	-0.09	-0.18	0.20	-0.03
mouthfeel	0.0001	0.3943	0.4882	0.5244	0.0858	0.0111	0.0294	1	0.85	0.19	-0.23	0.25	-0.18
overall	0.0027	0.0592	0.6104	0.8738	0.0360	0.0340	0.0522	0.0000	1	0.01	-0.46	0.42	-0.29
°Brix	0.2338	0.7694	0.4367	0.0266	0.4726	0.0167	0.5761	0.2294	0.9429	1	0.21	0.00	0.25
pH	0.2758	0.0000	0.8846	0.0027	0.0047	0.9543	0.2727	0.1399	0.0026	0.1780	1	-0.81	0.38
TA	0.1664	0.0000	0.1878	0.0922	0.0000	0.2658	0.2031	0.1092	0.0069	0.9771	0.0000	1	-0.14
phenolics	0.0972	0.6138	0.0000	0.0032	0.1450	0.3987	0.8574	0.2565	0.0713	0.1193	0.0160	0.3917	1

Correlations are between results from the first tasting (in red text) and laboratory measurements (in blue text). The numbers above the gray diagonal are correlation coefficients. Significant positive correlations are highlighted in blue and significant negative correlations are highlighted in orange. P-values are shown below the diagonal and those below 0.05 are highlighted in yellow.

Photo: Nicholas Smith

Ciders from Liberty apples were compared from two different orchards.

Comparing the same variety from two sources

The question remained whether ciders exhibit different qualities when made from the same variety of apples sourced from different orchards. To address this, the researchers collected Liberty and Kingston Black apples from two orchards—Cider House of Wisconsin and The Cider Farm—and made cider from each using the same methods.

The researchers compared Liberty ciders because the flavor profile is generally typical of American ciders, with average °Brix and acidity, and generally low levels of tannins. Liberty apples are disease resistant and may be preferred by organic growers and cider makers in humid ecoregions.

Tasters sampled the Cider Farm Liberty at the Wisconsin Fresh Fruit and Vegetable Growers Conference and evaluated the Cider House Liberty at the Willy Street Grocery Co-op tasting. Both were sampled at the first tasting event. In total, 23 tasters evaluated the Cider House Liberty and 26 tasters evaluated the Cider Farm Liberty. At the first tasting event, six tasters evaluated the Kingston Black ciders from both orchards.

On the following pages is a comparison of the laboratory data (Figures 6 and 8) and tasting results (Figures 7 and 9) for each variety. Overall, the Kingston Black laboratory values for °Brix are less variable than those for Liberty. The differences in tasting results are inconclusive, given the small number of tastings, but are nonetheless worthy of further investigation.

Different soils, management practices and other factors unique to each farm may contribute distinct flavors and chemical properties in ciders crafted from the same apple variety, brewed in the same way. The differences seen here show that more research will be needed to draw firm conclusions about what influences the chemistry and taste of cider apples, other than the specific variety.

Figure 6. Laboratory analysis comparing Liberty cider made from apples from two different orchards

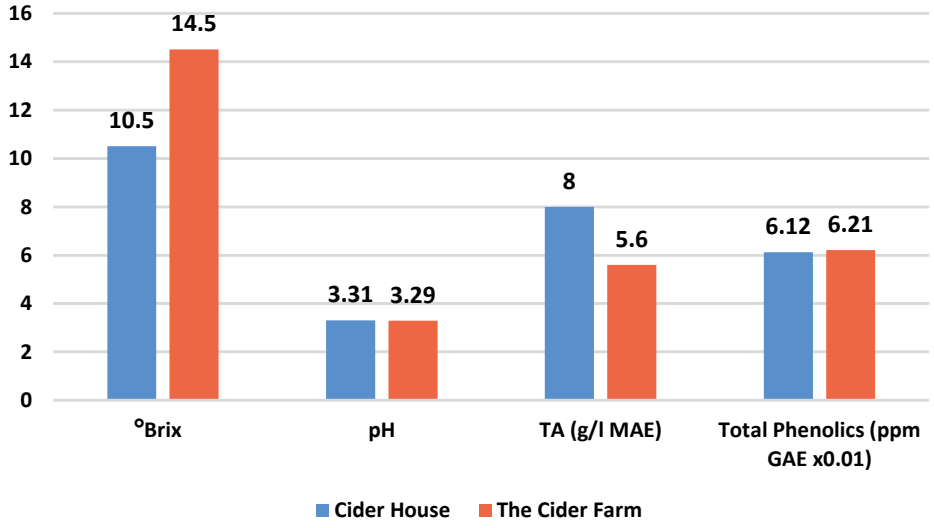
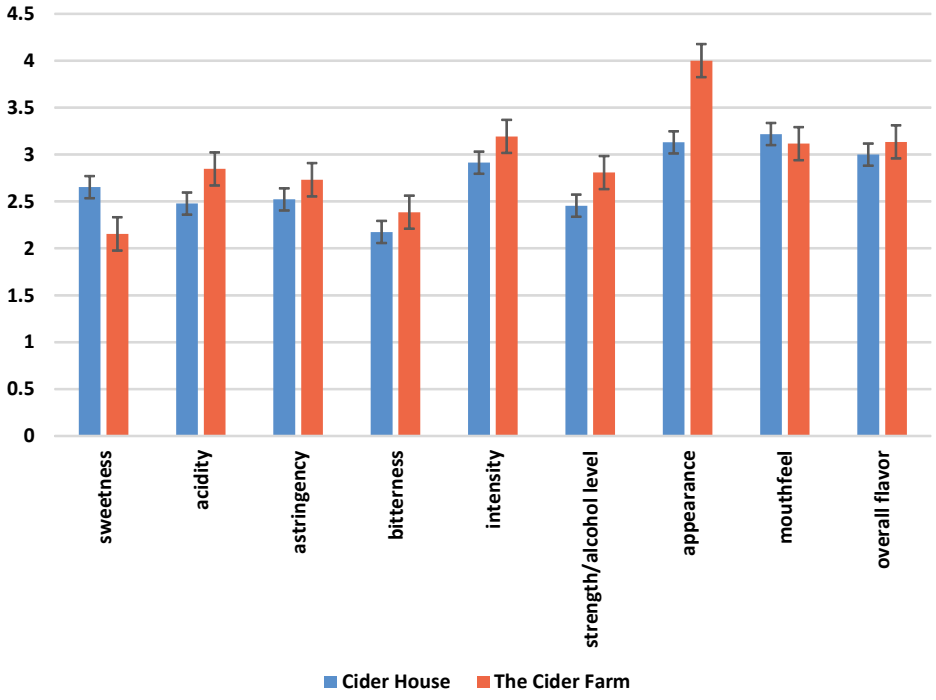


Figure 7. Tasting results comparing Liberty hard cider made from apples from two different orchards



Error bars are standard error of the mean

Results are from first tasting event

Figure 8. Laboratory analysis comparing Kingston Black cider made from apples from two different orchards

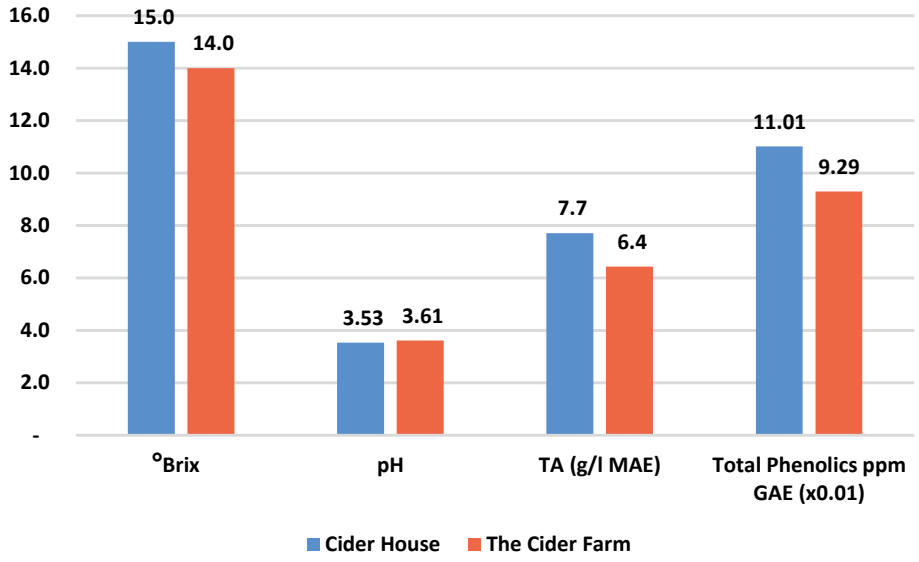
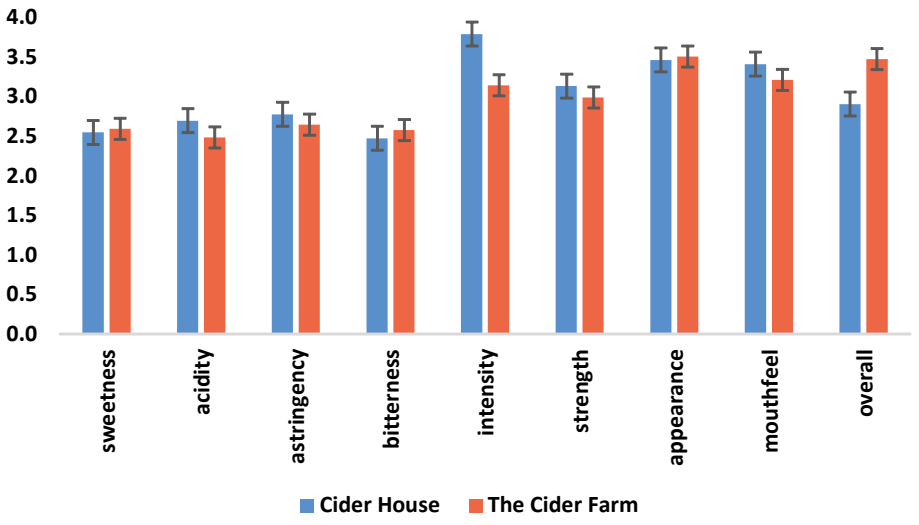


Figure 9. Tasting results comparing Kingston Black hard cider made from apples from two different orchards



Error bars are standard error of the mean

Results are from first tasting event

Discussion

The aim of this project was to help growers and hard cider makers select apples that result in high-quality, blended hard ciders with flavor profiles desired by consumers. The laboratory and tasting data resulting from this research can inform cider makers' and growers' decisions.

Tasting results are subjective and variable. The researchers intentionally chose people for each tasting group with different expertise. Although the researchers did not collect data on the age of the tasters, many were under 40, which is the primary demographic interested in hard cider.

The favorite (and least favorite) flavor profiles

While individuals have unique flavor preferences, some definite patterns emerged in this study. The ciders rated highest overall by the tasting panels were predominantly perceived as sweet or balanced in flavor, with preferences leaning towards higher perceived sweetness and acidity. None of the apples used in this analysis could be considered sweet by "eating apple" standards.

When tasting results were compared to laboratory data, the highest-rated ciders were negatively correlated with phenolics, which were closely associated with bitter and astringent flavor. This negative correlation may be due to the single-varietal ciders used in this research. The lowest-rated ciders had high levels of °Brix and TA, phenolics and TA, or all three. °Brix and phenolics are associated with the perception of bitterness, while TA is associated with acidity. Some of the apples, by themselves, were intensely bitter and would normally only be used to add complexity to a blended cider.

In this study, sugar levels were measured as °Brix before, but not after, fermentation. As a result, higher °Brix predicts the alcohol content, rather than the sweetness, of the finished ciders. °Brix was significantly correlated with bitterness and strength in the finished ciders, due to the higher alcohol content of ciders made from apples with higher °Brix.

Photo: Eleanor Voigt

Tasters in general preferred sweet or balanced-flavored ciders.

Limitations

The ciders analyzed and tasted in this project were brewed using the same methods, from apples produced and harvested over a single growing season (2017). However, factors beyond the researchers' control—including age of trees, orchard location, weather and management practices—may strongly affect the qualities of both apples and ciders. Illustrating this point is the variation found in

Photo: Ruth McNair

Cider researchers help participants during a grafting workshop.

laboratory and testing results in ciders from Liberty and Kingston Black apple varieties gathered from two orchards.

Many of the single-varietal ciders were tasted at only one event, and even those tasted at multiple events were sampled fewer times than is ideal. All of the tasting events were held over the course of a few months, minimizing the likelihood of flavor changes due to time.

The first tasting event had an adequate number of tasters for detecting significant sources of variation (for example, taster and variety). The small number of tasters at all tasting events may have led to a high degree of overlap in ratings between the single variety ciders. This is illustrated by the repetition in letters showing statistical differences in varieties from the first tasting in Figure 1 on page 9. However, this also means that the differences that the researchers did find were likely strong effects.

In designing future studies, it will be important to include more people in the tastings, track tasting panel demographics, and provide opportunities for tasting each variety multiple times.

Future research

The limitations discussed above provide direction for future research. To more accurately describe the chemical components and taste perception of hard ciders, multiple years of data collected from more locations are needed. Long-term trials in which the same apple varieties are gathered from the same farms, and brewed and tested over multiple years, would improve the accuracy of results. In a larger study, researchers may also gain a better understanding of how soil types, microclimates, weather or production practices might contribute to terroir, the "taste of place."

Laboratory testing for final sugar and alcohol content would improve understanding of the relationship between °Brix, fermentation, and perception of strength and astringency.

Expanded taste testing could provide a better understanding of demographic and experiential differences, and involve enough people to increase the certainty of the findings. Sampling fewer varieties, with selection based on these preliminary results or horticultural parameters, may allow for more robust results. Other testing methods could also be employed. For example, single-varietal hard ciders could be back sweetened with known levels of sugar to better understand consumer preference for sweetness.

Acknowledgements

We would like to thank our farmer partners for working with the campus team to identify hard cider apple varieties of interest, assist with securing samples, participate in the tastings and the grafting workshop, and review results. We extend our thanks to all tasting participants for sharing their time, palates and enthusiasm. We would also like to thank the Fermentation Sciences Program for making and storing the cider. Members of the Dawson Laboratory proved invaluable with setting up and running tasting events. Thanks to the reviewers of the report. This project was sponsored by the United States Department of Agriculture Sustainable Agriculture Research and Education (SARE) program in the North Central Region, project number ONC17-030, and the David S. Bourne Foundation.

APPENDIX A: ABOUT THE GROWERS

Submitted photo

Albion Prairie Farm

Albion Prairie Farm has over 100 heirloom apple varieties. Their Albion Prairie Farm Apple Brandy is aged in charred oak bourbon barrels using only apples harvested and pressed on their farm. They harvest all of their pesticide-free apples by hand and press the cider in their former tobacco barn using a 1913 apple cider press.

Submitted photo

Brix Cider

In 2014, Marie and Matt Raboin started planting trees for Brix Orchard, which in 2018 had grown to over 1,000 trees and nearly 100 apple varieties representing many different types of potentially interesting cider apples. They formed Brix Cider in 2016 and developed a unique supply chain, sourcing apples from 14 small farms in the Driftless region of Southwest Wisconsin.

Submitted photo

The Cider Farm

The Cider Farm specializes in organically growing English and French cider apples in southwestern Wisconsin for its own line of apple brandy and ciders that are sold in Wisconsin and Illinois.

Cider House of Wisconsin

Cider House of Wisconsin produced apple juice and apple cider for several years. They sourced the trees in their thirty-year old orchard from over a dozen different nurseries in as many states. They pressed and fermented cider from their own apple

APPENDIX B: FARM SOURCES FOR APPLE VARIETIES

Variety	Farm
Antonovka	Cider House of WI
Bergere	Brix Cider
Berne Rose	Cider House of WI
Blushing Gold	Cider House of WI
Brown's Apple	The Cider Farm
Cap of Liberty	Albion Prairie Farm
Chisel Jersey	The Cider Farm
Cinnamon Spice	Albion Prairie Farm
Crittenden Crab	Brix Cider
Dabinett	The Cider Farm
Driftless Cider	Brix Cider
Fayette	Albion Prairie Farm
Freedom	Cider House of WI
Golden Russet	Brix Cider
Hoople's Antique Gold	Brix Cider
Kandil Sinap	Cider House of WI
Kingston Black CH	Cider House of WI
Kingston Black CF	The Cider Farm
Liberty CH	Cider House of WI
Liberty CF	The Cider Farm
Major	The Cider Farm
Malinda	Brix Cider
NY 74828-12	Cider House of WI
NY 75413-30	Cider House of WI
Old Nonpariel	Brix Cider
Priscilla	The Cider Farm
Red Delicious	Cider House of WI
Redfield	Albion Prairie Farm
Rosemary Russet	Albion Prairie Farm
Royal Russet	Brix Cider
Ruppert's Sweet	Brix Cider
Secor	Albion Prairie Farm
Somerset Redstreak	The Cider Farm
St. Lawrence	Cider House of WI
Steele Red	Albion Prairie Farm
Stembridge Jersey	Albion Prairie Farm
Swaar	Brix Cider
Thornberry	Albion Prairie Farm
Tremlett's Bitter	The Cider Farm
Unknown 1	The Cider Farm
Unknown 2	Albion Prairie Farm

APPENDIX C: LABORATORY ANALYSIS OF CIDER CHARACTERISTICS

Figure C1. pH levels of the juice used for the 41 single-varietal ciders. The ideal range, represented by the light blue bars, is about 3.2 to 3.8.

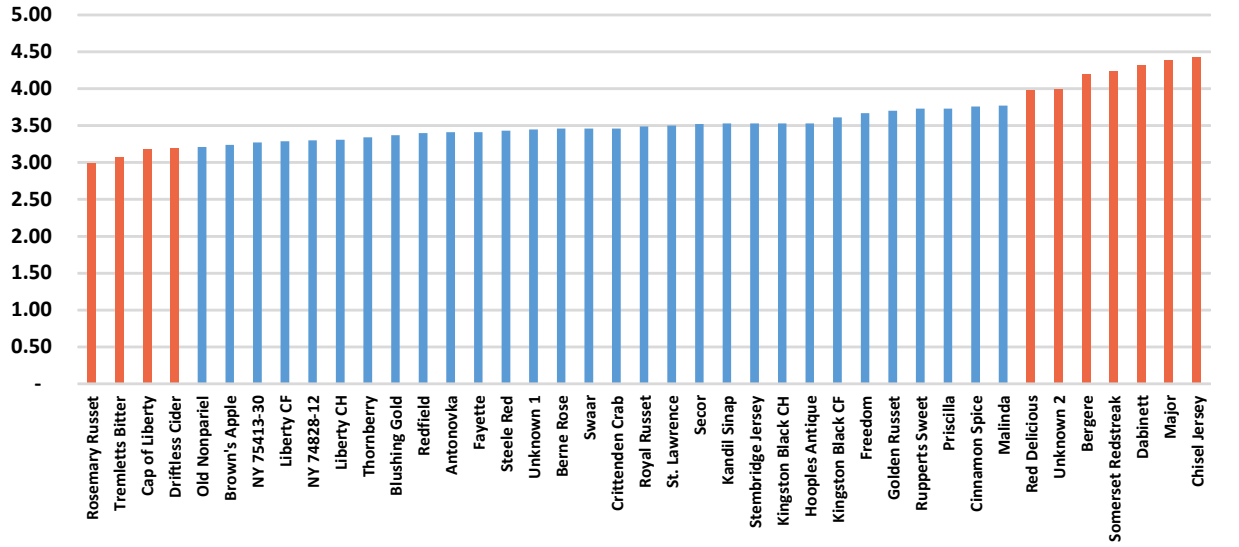


Figure C2. TA, g/l MAE (malic acid equivalent), of the juice used for the 41 single-varietal ciders. The ideal range represented by the light blue bars, is about 4.5 to 7.5 g/L MAE.

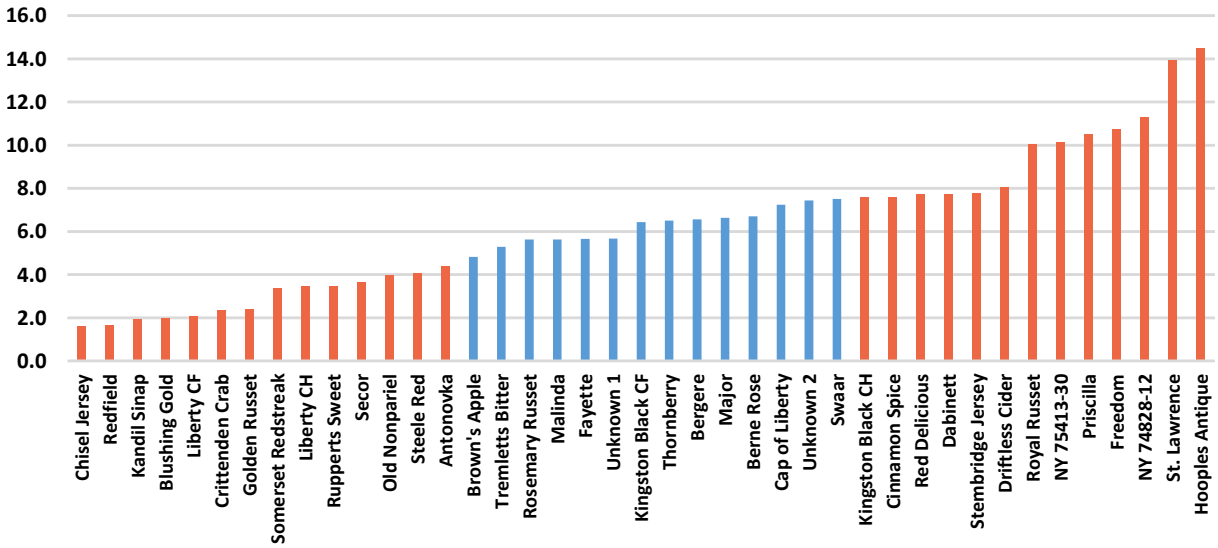


Figure C3. Degrees Brix level (g of sugar per 100 g of solution) of the juice used for the 41 single-varietal ciders. The ideal range, represented by the light blue bars, is about 11 to 15. The researchers did not measure final sugar and alcohol content of the ciders.

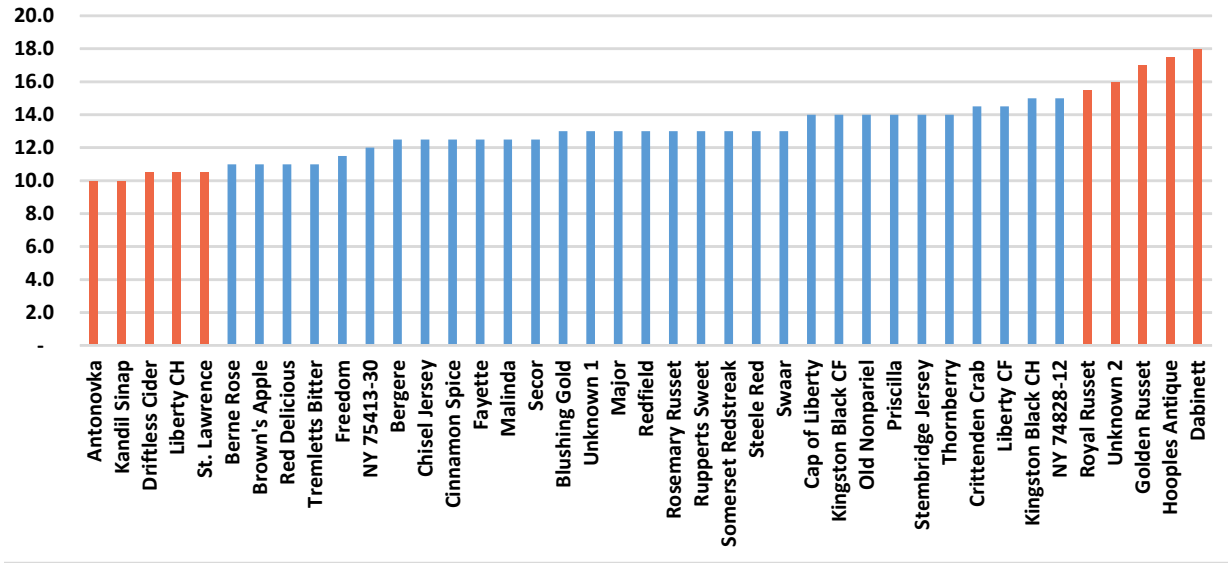
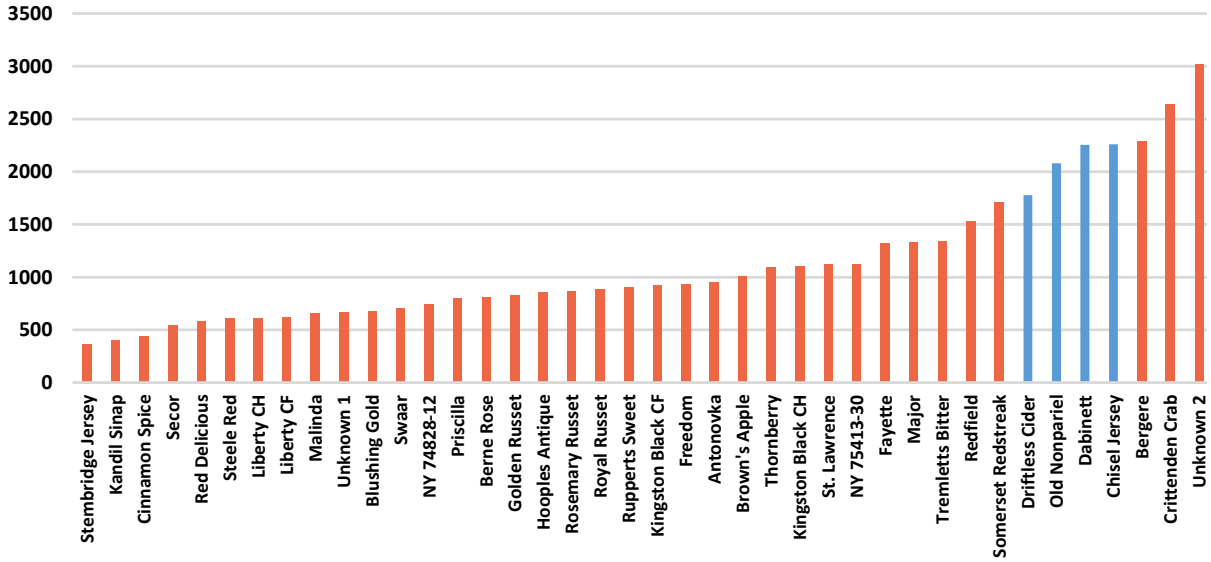


Figure C4. Total phenolics, ppm GAE (gallic acid equivalents measured using the Folin-Ciocalteu Method), of the 41 single-varietal ciders. The ideal level for a finished hard cider is about 2,000 ppm GAE; the ciders closest to this level are in light blue. No data was recorded for Cap of Liberty.



APPENDIX D: DATA ANALYSIS

Data from the first tasting was analyzed with a mixed model analysis of variance (ANOVA) using the *lmer* function of the lme4 package in R statistical software.[1, 2] Varieties were considered fixed, with tasters, replications and incomplete blocks considered random effects. Varieties were sampled from particular plantings and only from one year, so are not necessarily representative of that variety across a range of environmental conditions. The statistical means for each flavor component of each variety were obtained with the *lsmeans* function in the R package.[3] LS means for each of the flavor components (bitterness, astringency, sweetness, and acidity) for each variety were then included in a principal component analysis (PCA) using the PCA function in the R package FactoMineR.[4] PCA is a common statistical technique used to visualize multi-dimensional data. For the subsequent tastings, all tasters tasted all varieties, so the *lmer* function was used considering taster as a random effect and variety as a fixed effect.

Correlations between laboratory data for °Brix, TA, pH and phenolics and flavor components (using variety means) for each tasting were calculated using the *cor* function in the base R stats package.[5] Correlations were tested for statistical significance using the *rcorr* function of the Hmisc package in R.[6] A multiple factor analysis (MFA) was used to combine the laboratory data and the results of the first tasting using the *MFA* function in the R package FactoMineR. MFA is essentially a PCA that balances the contribution of groups of variables, in this case the flavor components as one group and the laboratory data as another group. This is useful when combining different types of measurements taken on significantly different scales.[7]

[1]Douglas Bates, et al., "Fitting Linear Mixed-Effects Models Using lme4," *Journal of Statistical Software*, 67, no. 1 (October 2015): 1-48, (accessed 3/25/19); available from https://www.jstatsoft.org/article/view/v067i01/v67i01.pdf.

[2]R Core Team. "R: A language and environment for statistical computing." Vienna, Austria, (2016): R Foundation for Statistical Computing, https://www.R-project.org/.

[3]Russell V. Lenth, "Least-Squares Means: The R Package lsmeans," *Journal of Statistical Software*, 69, no. 1 (January 29, 2016): 1-33, (accessed 3/25/19); available from doi:10.18637/jss.v069.i01 use this? https://www.jstatsoft.org/index.php/jss/article/view/v069i01/v69i01.pdf

[4]Sebastien Le, Julie Josse, and Francois Husson, "FactoMineR: An R Package for Multivariate Analysis," *Journal of Statistical Software*, 25, no. 1(2008): 1-18, (accessed 3/25/19); available from http://factominer.free.fr/more/article_FactoMineR.pdf.

[5]R Core Team, 2016.

[6]Frank Harrell, Jr., et al., "Hmisc: Harrell Miscellaneous." R package version 4.0-3, 2017, (accessed 3/25/19); available from https://CRAN.R-project.org/package=Hmisc.

[7]Julie Dawson, and Kitt Healy, "Flavor Evaluation for Plant Breeders," *Plant Breeding Reviews*, 41 (26 January 2018): 215-262, (accessed 3/27/19): available from https://onlinelibrary.wiley.com/doi/abs/10.1002/9781119414735.ch5.

APPENDIX E: CIDER CHARACTERISTICS FROM FIRST TASTING

Tasters at the first event rated the single-varietal ciders on a range of characteristics. They rated these characteristics on a scale from 0=very bad to 5=excellent. Results are shown in Figures E1 through E8.

In all of these graphs, bars marked with the letter 'a' are statistically different than those marked without an a, and so on for each letter shown.

Figure E1. Acidity ratings, from the first tasting of 41 single-varietal ciders

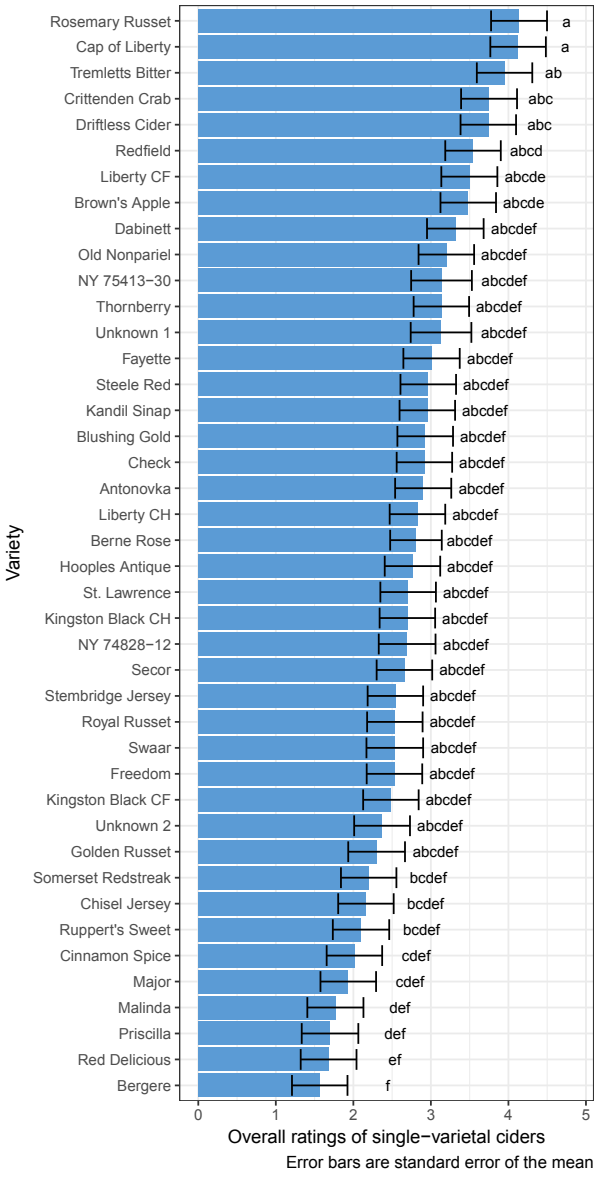


Figure E2. Appearance ratings, from the first tasting of 41 single-varietal ciders

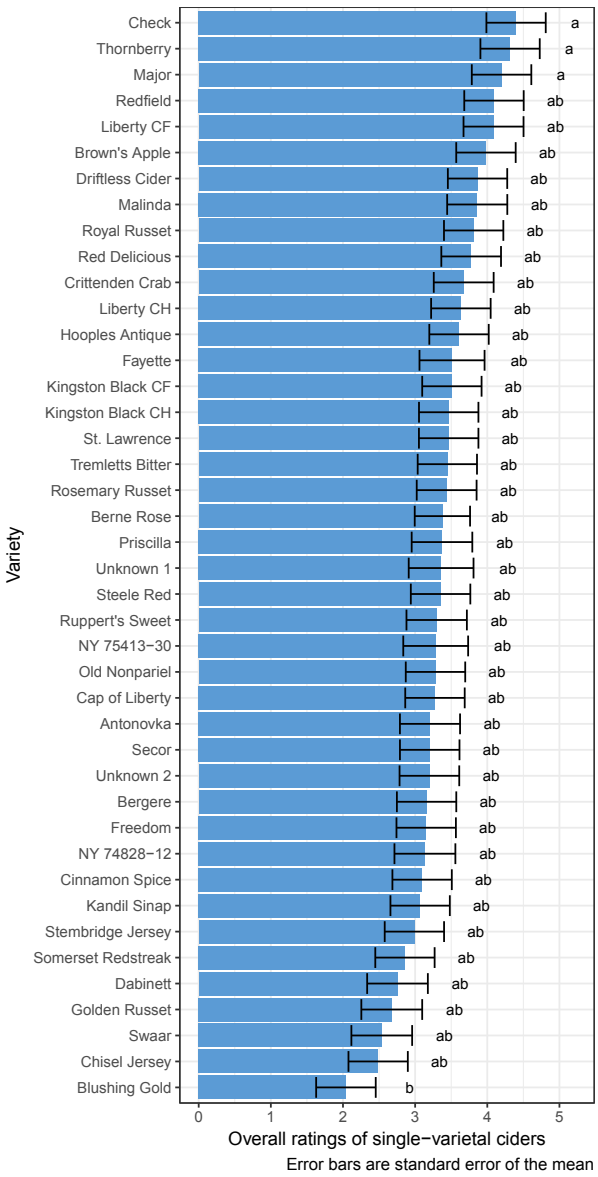


Figure E3. Astringency ratings, from the first tasting of 41 single-varietal ciders

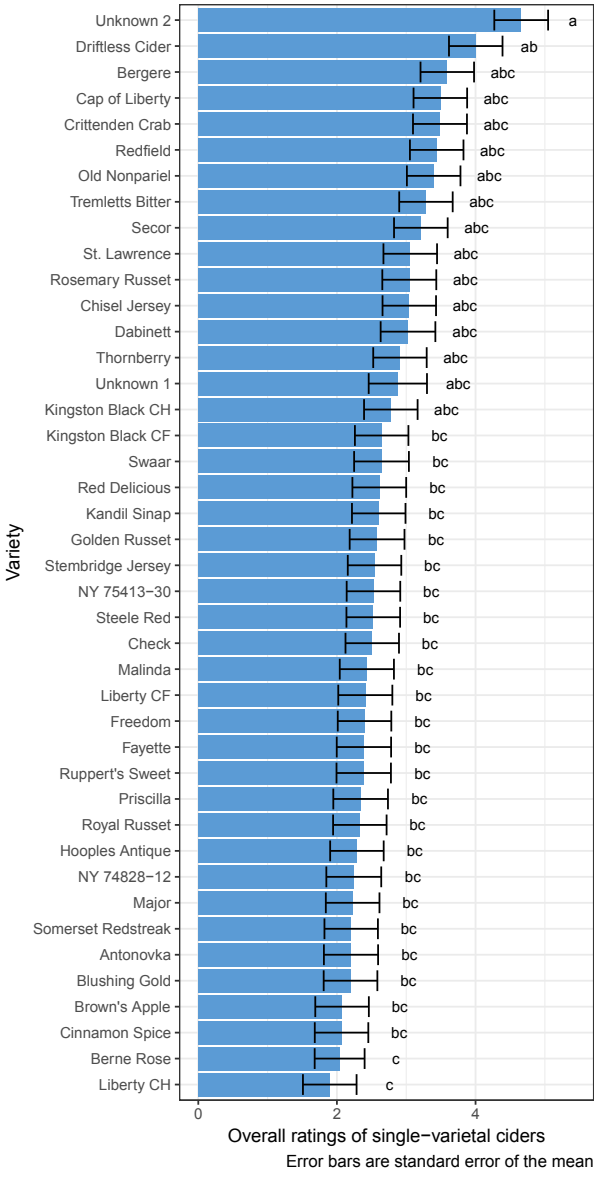


Figure E4. Bitterness ratings, from the first tasting of 41 single-varietal ciders

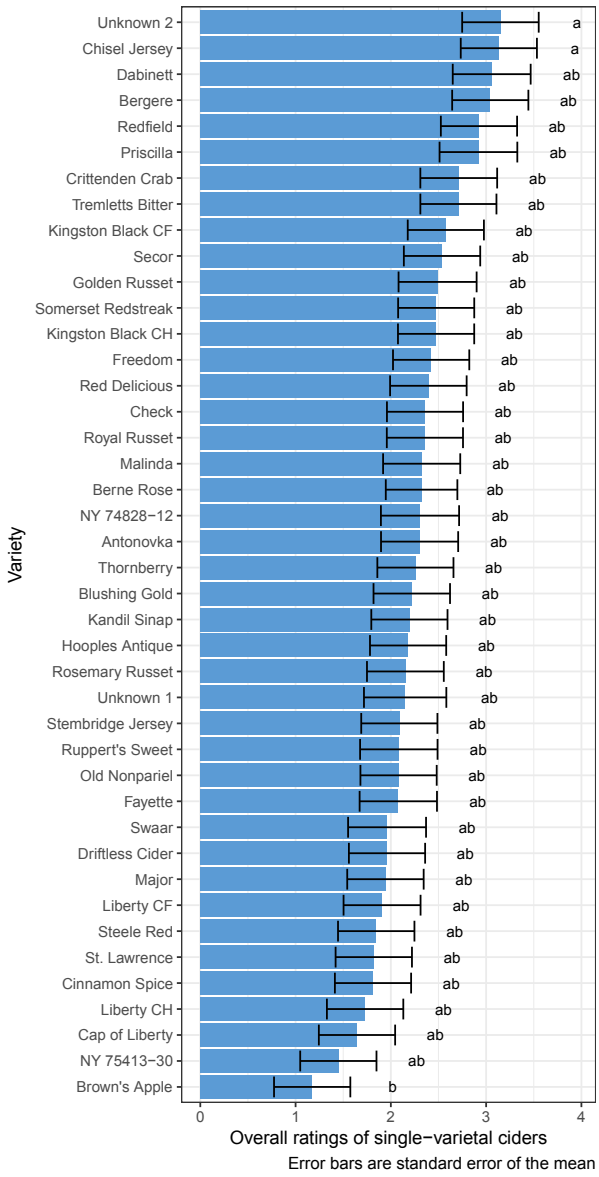


Figure E5. Intensity ratings, from the first tasting of 41 single-varietal ciders

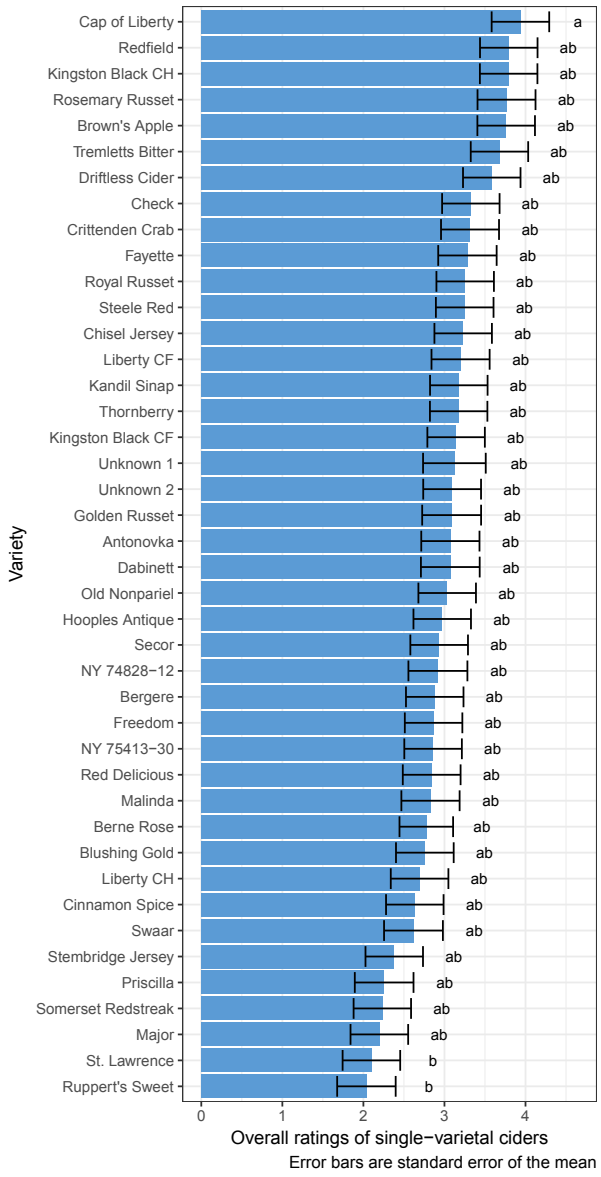


Figure E6. Mouthfeel ratings, from the first tasting of 41 single-varietal ciders

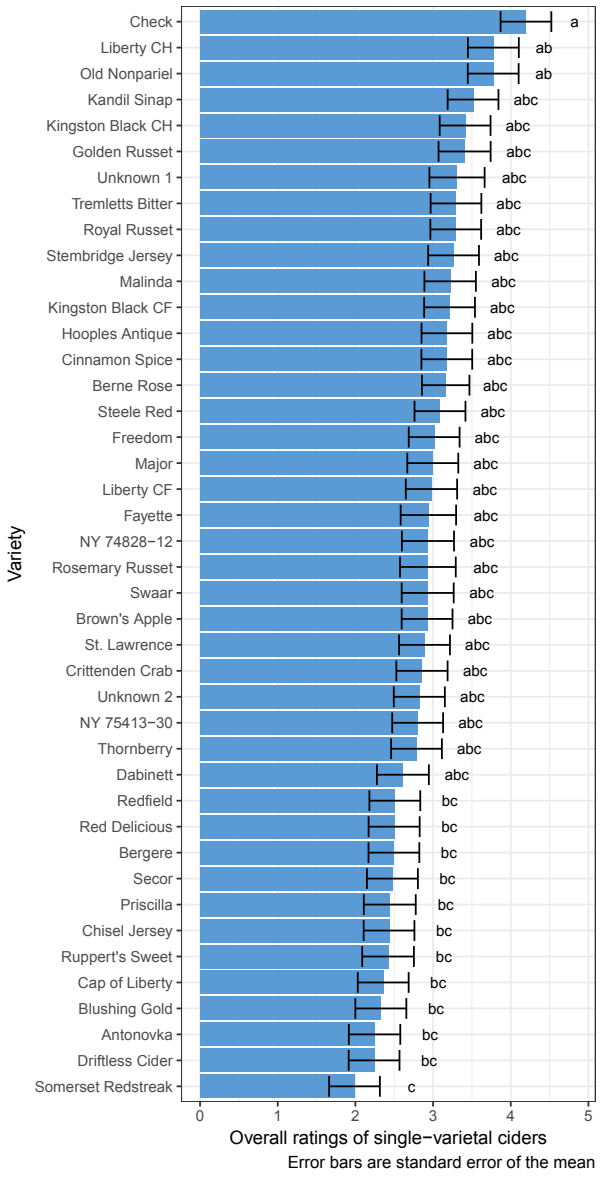


Figure E7. Strength ratings, from the first tasting of 41 single-varietal ciders

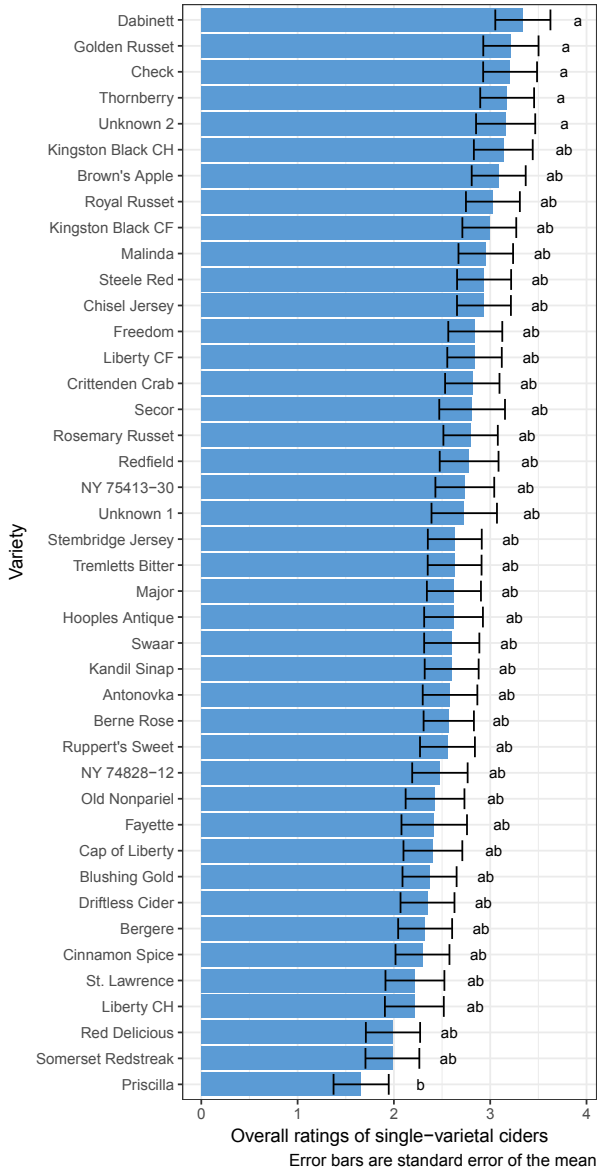
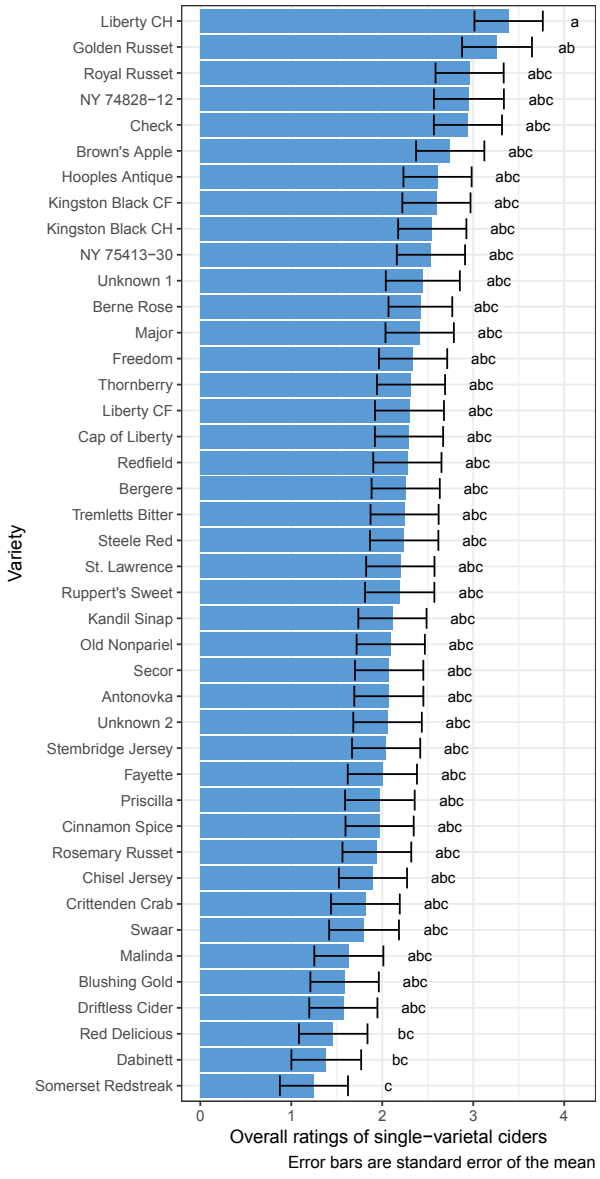


Figure E8. Sweetness ratings, from the first tasting of 41 single-varietal ciders



APPENDIX F: OUTREACH AND IMPACT

Matt Raboin (farmer/cider maker), Nick Smith (Master Fermenter at UW-Madison Fermentation Lab), Michelle Miller (researcher at UW-Madison-CIAS), and Eleanor Voigt (project manager, UW-Madison CIAS) presented preliminary results from this study at the Wisconsin Fresh Fruit and Vegetable Conference (https://projects.sare.org/information-product/apples-for-artisan-cider-with-michelle-miller-and-matt-raboin-2/). Attendees were orchardists, hard cider makers and wine grape growers. (In Wisconsin, hard cider is regulated as a type of wine.) Many were interested in the idea of single-varietal tasting.

A compilation of cider variety profiles is available in Appendix G. These profiles describe each variety individually, with images, horticultural notes from the growers, laboratory results and notes from the tastings, including flavor and mouthfeel of a cider made solely from that apple variety. This can help people interested in growing hard cider apples identify and select which apples to grow, and assist cider makers in understanding what each apple variety may add to a finished, blended cider product.

Associated with this project, CIAS offered a free public grafting workshop on April 21, 2018. This workshop was a chance for attendees to learn about the grafting process so they can propagate heirloom apple varieties specifically used for hard cider. The fifty participants learned about the overall project, and how to access the information on specific apple varieties.

The economics of hard cider production and supply chain issues are other areas of concern for artisan cider makers. In collaboration with faculty at Washington State University, Michigan State University and the University of Vermont, staff at the UW-Madison CIAS are exploring these issues and learning from craft hard cider industries in other regions. This work is made possible with support from the USDA-AFRI Small Farms program.

APPENDIX G: PROFILES OF HARD CIDER APPLE VARIETIES

by Eleanor Voigt

The Apples to Apples project evaluated 41 single-varietal ciders, pressed and fermented in the fall of 2017, at four tasting events. CIAS partnered with the UW-Madison Department of Horticulture and the Fermentation Lab in the Department of Food Science on this project. The following pages provide growers' horticultural observations of each apple variety and tasters' comments on each cider sampled at these events.

This report is organized alphabetically by variety and includes pictures of each apple, growers' observations, and tasting data describing the cider produced from each variety. More detailed information is provided for the promising varieties selected for multiple tastings. See Table 1 in the "Materials and methods" section of the *Comparing Apples to Apples* report for information on tasting methods and events in this project. The full report also provides the lab results for these ciders. The taster comments were provided by people not professionally trained as tasters, and with no specific guidance on terminology. Not all tasters provided comments. Therefore, while the taster comments are interesting, they should be considered within these limitations.

Albion Prairie Farm, Brix Cider, The Cider Farm and Cider House of Wisconsin supplied the apples for this project. The growers' notes for each variety provide observations of the trees and fruit that have not necessarily been replicated through research. Tree and fruit qualities, productivity and performance may differ with location and growing conditions. Matt Raboin of Brix Cider and Deirdre Birmingham of The Cider Farm provided observations and comments for many varieties. The notes on the varieties from the Albion Prairie Farm are from *The Illustrated History of Apples in the United States and Canada,* authored by Daniel Bussey, the previous owner of the orchard. When he writes that a tree is not subject to any particular problems, he has observed that the tree will not suffer more than an average tree under stress. He is not claiming pest or disease resistance.

The art of cider making lies in blending apple varieties to achieve characteristics such as complex, balanced flavors and an appealing color. When reading these descriptions, keep in mind that these ciders were not blends, but made from a single variety. While a single variety cider may not stand alone, as sometimes evidenced by the tasting results, combined with other varieties it could make wonderful cider.

Antonovka

Grower Notes - Cider House of Wisconsin

Yellow or red, round apple with white flesh. Very cold tolerant. Good rootstock. Pink-tinged flowers.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties

Farm-y, homemade taste

Bergere

Grower Notes - Brix Cider

This cider hailed from the apples of a wild tree found where an old orchard had been cut down in Southwest Wisconsin. The small tree bore a very heavy crop of medium-sized apples. The apples were in good condition despite no orchard care. They did show a fair amount of sooty blotch and flyspeck, which are mostly of cosmetic concern and unimportant for cider apples. The tree shows potential as a cider apple, as the fruit provides an intense bitterness that could add complexity in a blend with common dessert apples.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties; Tasting event 2-farmers and chefs; Tasting event 4-co-op employees

Oxidized, wood, musty, earthy, green, leathery with slight bitterness, bitter, astringent, tart, apple flavor yet still dry, dry, nice balance, lacks distinction, flat, soapy, alcohol, carbonation, carbolic, acid

Color and Mouthfeel	Strongest Attribute	Weakest Attribute
Hazy, champagne, golden/pink, watery, dry, bubbly but not enough, light in color, crisp and bubbly, slight fizz	Complexity, astringency, discreetness, strong flavor towards the throat, apple flavor, fizz and bitterness	Mouthfeel, fungal, flavor absent, acidity is strong and could be too drying in excess

Berne Rose

Grower Notes - Cider House of Wisconsin

Red apple with green striping and firm flesh

Hard Cider Flavor Descriptions - Tasting event 1-all varieties

Banana

Blushing Gold

Grower Notes - Cider House of Wisconsin

Yellow apple with dirty orange-pink blush

Hard Cider Flavor Descriptions - Tasting event 1-all varieties

Thick and bland, bland

Brown's Apple

Grower Notes - The Cider Farm

Vigorous with good central leader. Fire blight sensitive. Somewhat biennial. Earlier bloomer. Early harvest. Apples start to drop, but not all will drop.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties; Tasting event 4-co-op employees

Floral, rose-like, melon, very apple-y, pear aroma, citrus, sour, dry, crisp, complex, full-bodied, sparkly, yeasty, stale, vinegar, wormy, earthy

Cap of Liberty

Grower Notes - Albion Prairie Farm

Cap of Liberty is a full, bitter-sharp cider variety from Martock, Somerset, England and was known as of 1873. The tree is moderately vigorous and somewhat 'rangy' with multiple leaders and unbranched spreading limbs. Consideration of dwarfing rootstocks might help with tree form and fire-blight pressure. It is reported that this apple does better on limestone soils. The variety is susceptible to scab, water-core, canker and apple sawfly. The apple blooms a little earlier than average. Frost pockets should be avoided. Fruit cropping is good but a little irregular. Fruit skin is yellow-green, dry and slightly rough. Cider of this apple is of good 'vintage' quality with a clean fruity taste; fermentation can be a bit slow (SG about 1055 and fairly high acid). This apple has been a good grower despite its reputation. No significant problems outside of some susceptibility to fire-blight.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties; Tasting event 2-farmers and chefs; Tasting event 4-co-op employees

Fruity, melon-y, citrus , apple, apple undertones, pear, caramel, sour dust, sour, sour candy, sour warhead candy flavor, warhead tartness, tart, bitter, very astringent, strong, sweet, too sweet, sweet and sour, tasty, sparkly, fizzy, wine-y, acidic, acid, vinegar, yeasty, wild, sulphuric, SO2, rotten egg smell, rancid, needs sweet to balance, would be good blended with Swaar and Liberty CH

Cap of Liberty, continued

Color and Mouthfeel	Strongest Attribute	Weakest Attribute
Rosy, biting, bubbles, pink, pink/gold, light, nice pinkish color, best yet, pink blush orange, light, pink, bubbly, nice fizz, way too red in color but flavor is okay	Complex intensity, tart, very tart, beautiful color, sour and sweet balance	Too biting, bitter, too sweet, needs some sweet, dry

Chisel Jersey

Grower Notes - The Cider Farm

Similar in growth habits to Dabinett, but in this farm's experience more prone to fire blight. Good crop every year.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties; Tasting event 2-farmers and chefs

Strawberry, tannic acidity, wine-alcohol, acrid, not sweet, sour, bitter, medical, bitter, slightly sweet, would be a good component of dry cider

Color and Mouthfeel	Strongest Attribute	Weakest Attribute
Rust color, hazy, golden, golden warm dry, yeasty/ bubbly, flat, think, wine-like, apple juice color, crisp and bubbly, slight fizz	Tannic, Pabst-like but flat, crisp, nice, bitter, slight sweet	Lingering bitter, yeasty, lacks crispness, not sweet enough, a little boring

Cinnamon Spice

Grower Notes - Albion Prairie Farm

California variety from the Bolinas – Olema Valley. Fruit is generally medium in size but can run smaller. The skin is predominantly wine-red over yellow ground color. The flesh is very rich, with a cinnamon-like flavor that lasts a long time after eating. A lovely intense flavor. The tree is somewhat to moderately vigorous with upright shoots; needs attention to training to maintain good shape. Ripens late October. The tree has survived nicely in hardiness region 4b – 5a without any particular problems.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties

Unusual

Crittenden Crab

Grower Notes - Brix Cider

Crittenden Crab is primarily ornamental and good for birds and wildlife, due to its abundant flowers and heavy crop of bright red and yellow fruit that persists well into winter. We included it in the experiment out of curiosity, but the small fruit size would not make it viable for an orchard production system.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties

No notes

Dabinett

Grower Notes - The Cider Farm

Non-vigorous. Nice tree structure with good branch angles. Sensitive to fire blight. Known to be sensitive to soil K-deficiency. Good crop every year.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties; Tasting event 2-farmers and chefs; Tasting event 3-conference

Fruity, melon, citrus, sour, bark, malty with tannins, tannin, bitter in front and back of mouth, bitter finish, moderately bitter, high bitterness, high in alcohol and bitterness like moonshine, IPA of ciders, very dry finish, bland, low in sour and sweetness, slightly sweet, sweet, rubbery, waxy on roof of mouth, would buy in a blend, almost like a tincture, medicinal, musty, yeasty aroma, bittersweet apple, out of balance, try mixing with golden russet

Color and Mouthfeel	Strongest Attribute	Weakest Attribute
Cloudy, light gold, apple juice color, apricot, dry, golden, flat, bitter, smooth	Maltiness, alcohol content, thoroughly bitter, complexity	Bitterness, sweets, woody, no balance/ flavor, rubbery aroma, flat, tastes like soap, ABV (alcohol by volume) too high, out of balance

Driftless Cider

Grower Notes - Brix Cider

Wild apple tree found in Southwest Wisconsin. Brix Cider harvested several bushels of medium sized apples from the same tree, two years in a row. Apples were in good condition, despite no orchard care. The lingering astringency of the apple, plus its acidity, gives it good blending potential for complex ciders.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties; Tasting event 4-co-op employees

Fruity, black currant, citrus-y, “fake” apple, bitter , astringent, acidic, solvent-like, caustic, sour, slightly sour, watered down, powdery

Fayette

Grower Notes - Albion Prairie Farm

This apple was sourced from the Raven Island Nursery on Waldron Island, Washington. It's one of the best apples for fresh eating and is exceptional for cider because of its rich sugar-acid balance and great aroma. The fruit is medium size, yellow with orange-red blush and overall russet. The flesh is yellowish, crisp, fairly fine-textured and of excellent quality. The fruit is said to store well. Scab is not an issue nor has fire-blight been any sort of problem. The tree is an upright grower and should be trained early to maintain good tree shape. Should be better known than it is!

Hard Cider Flavor Descriptions - Tasting event 1-all varieties

No notes

Freedom

Grower Notes - Cider House of Wisconsin

A reliable producer with fairly large apples. Management is pretty simple because it is a disease-resistant variety. The apples have a pretty limited shelf life, but are good for eating fresh.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties

Grape, apple peel, 4-EP (a phenolic compound produced by the spoilage yeast Brettanomyces that can cause desirable or undesirable flavors)

Golden Russet

Grower Notes - Brix Cider

One of the most well known of the russeted apples, Golden Russet is often used by cider makers due to its typically high brix and rich flavor. Fruit generally ripens in October. The 30 Golden Russet trees in Brix Cider's orchard are not performing well, compared with other apple varieties. The apples for this study were picked from a tree at Seed Savers Exchange. It bore a medium crop, but many of the apples had to be discarded due to insect damage and rot.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties; Tasting event 3-conference

Rose-like, banana, peach, apple, baked apple, apple juice/ apple candy, watery, culinary, candy hearts and Belgian beer, a bit sour, off, odd aftertaste, vinegar, chemical, estery, brett, low acetic acid

Hoople's Antique Gold

Grower Notes - Brix Cider

Mostly russeted apple discovered in Ohio as a "sport" of Golden Delicious. Medium sized, very flavorful apple that ripens late in the season. The tree at Seed Savers Exchange, where we harvested these apples, provided a good crop of healthy apples, without any spraying.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties

Vinegar, butter, brandy-like, off-aroma but good flavor

Kandil Sinap

Grower Notes - Cider House of Wisconsin

Cylindrical shaped apple, color washes from red to yellow to green with white flesh. Grapefruit scent and balance of sweet and sour. Skinny tree that originated in Turkey.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties; Tasting event 2-farmers and chefs

Fruity, bubble gum, sour and grassy, dry, bitter, tart, fizzy, bitter, slightly bitter/sweet, astringent, bright, dry, acidic, sour, acidic, needs sweet to balance, acid, little complexity, hint of aroma

Color and Mouthfeel	Strongest Attribute	Weakest Attribute
Light and tangy, flat, clear, golden, yellow, light gold, white wine, watery, thin, flat, golden, light, smooth, apple juice color, crisp and bubbly, yellow, crisp, amber, smooth	Unusual flavor up front, bitter back end, color smoothness, apple and astringent balance, flavor intensity	Plastic aftertaste, missing a base flavor, smooth, no flavor on the front, not enough apple, too dry, acidic, one-note flavor, low complexity

Kingston Black CH

Grower Notes - Cider House of Wisconsin

Produces mild, bitter-sharp juice, slow to start bearing, red apple

Hard Cider Flavor Descriptions - Tasting event 1-all varieties

Smells like fake butter, dark orange color

Kingston Black CF

Grower Notes - The Cider Farm

Moderately vigorous. Does not produce a good tree structure. Prone to scab and fire blight. Can be a light cropper.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties

Good tannin blender, good blender, floral, good, bananas

Liberty CH

Grower Notes - Cider House of Wisconsin

Deep red apple, disease resistant. Crisp, juicy flesh, trouble-free management.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties; Tasting event 2-farmers and chefs; Tasting event 4-co-op employees

Fruity, grape, banana, little apple flavor, like white wine, anise, bitter, dry, drying, sweet, tart throughout but good intensity, sharp, sour, sour yet flavorless, sour vinegar, acidic, very acidic, only one note, bland, blah, flat, viscous, warming, light, ester-y

Color and Mouthfeel	Strongest Attribute	Weakest Attribute
Medium color, pale yellow, golden, light color, tannic finish, bubbly, bubbly but still needs more bubbles, sticky mouthfeel	Acidic, bitter, tart and bitter intensities, sour	Bland finish, sweet, similar to royal russet but not as good, needs more tartness, mouthfeel too acidic, one note

Liberty CF

Grower Notes - The Cider Farm

Consistent cropper. Resistant to fire blight, cedar-apple rust, and scab. Easy to grow. Plum Curculio-resistant like Liberty. Harvest in early- to mid-October.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties; Tasting event 3-conference

Floral, very floral, strong apple flavor, bittersweet apple, apple, Macintosh, citrus, fruity, tart, smooth, sweet, round, yeast, dry, flat, tastes young and flat

Major

Grower Notes - The Cider Farm

Produces lots of branches, making it a bushy tree. Slow to produce. Late blooming. Small apples that stay green. Prone to rot and water core. **Brewer note:** Did not press well.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties

Slight anise, juice, sour

Malinda

Grower Notes - Brix Cider

A pleasantly sweet apple with a pear/citrus-like flavor. Malinda is the parent of many apples that came out of the University of Minnesota breeding program, chosen in part because of its cold hardiness. The source tree at Seed Savers Exchange bore a very heavy crop of nearly unblemished apples, even without spraying.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties

Banana, leather, interesting flavor—could be good in a blend, flowers, nutmeg, bubbly

NY 74828-12

Grower Notes - Cider House of Wisconsin

Red apple

Hard Cider Flavor Descriptions - Tasting event 1-all varieties

No notes

NY 75413-30

Grower Notes - Cider House of Wisconsin

Red apple

Hard Cider Flavor Descriptions - Tasting event 1-all varieties

Peach/apricot, sour, thin

Old Nonpariel

Grower Notes - Brix Cider

An old French apple variety, known to provide a fairly good crop on trees with average vigor. The tree at Seed Savers Exchange where this apple was harvested had produced a good crop of medium sized, flavorful apples that were in good condition, without any spraying.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties; Tasting event 3-conference

Fresh apple, fruity, sharp, crisp, tart, bitter, acidic, medicine, green/wasabi/horseradish, weak, off, too much acid—can't taste anything else, bad intensity, plain, sour

Priscilla

Grower Notes - The Cider Farm

Resistant to fire blight, cedar-apple rust and scab. Easy to grow. Consistent cropper. Apples can split with rainfall near harvest. Harvest in mid-September.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties

No notes

Red Delicious

Grower Notes - Cider House of Wisconsin

Intensely red apple. Thick, bitter skin. Yellow flesh. Keeps good looks even after flavor is gone.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties; Tasting event 3-conference

Caramel, toasted, floral, geranium, butter, interesting aromatics, nice complexity— could use some fruitiness, flavor on its own is not that good, but could be an interesting blender, off, bad, dirt, metallic, watery, thin, not much flavor, flat, light, blah, pasty

Redfield

Grower Notes - Albion Prairie Farm

This is a 1924 cross of Wolf River x *Malus niedzwetskyana* (Russian redflesh crab) from the New York State Experiment Station at Geneva. The fruit grows to a full medium-to-large size. The skin color is very dark red and the flesh inside is reddish in the outer half (near the skin) and cream colored in the inner half (near the core). The flesh is fairly firm, dry, coarse, not aromatic and sour, but it adds a good flavor and color to ciders. The tree is a stocky, healthy grower with ornamental qualities of dark green leaves and grayish wood. This apple blooms about four days (on average) before Delicious and ripens after Delicious in late October. No particular problems growing this tree or fruit.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties

Too orange colored, not great appearance, rose color, sour ferment flavor

Rosemary Russet

Grower Notes - Albion Prairie Farm

This is an English dessert russet known as of 1831. Fruit is oblate conic, a little bit ribbed and medium in size. Skin: yellowish green with a brownish-red blush and covered with a light brown russet. The flesh is white tinged greenish to yellowish, firm, fine textured and sweet/subacid. It has a good sugar-acid balance and is aromatic. Overall, a pleasant apple for fresh eating and cider.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties

Cherries, acid

Royal Russet

Grower Notes - Brix Cider

An older English variety. Limited information is available on this uncommonly grown, russeted apple. The source tree at Seed Savers Exchange had a medium crop of smallish apples that were highly flavored.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties; Tasting event 2-farmers and chefs

Yum, would be a good component, best balance of the group, needs sweet to balance, strong fruit, wine (grape), no apple taste, green apple, grapefruit, tart, thoroughly mediocre tartness, cotton candy, dry, slightly sour, acid, slight sweet, light, good, clean

Color and Mouthfeel	Strongest Attribute	Weakest Attribute
Light color, light, light yellow, pale yellow, golden, balanced mouthfeel, smooth, feels light, flat, watery, bubbles, bubbly and crisp	Balance, floral, sweet, good taste, tart only, dry	Lacks dimension, strong acid

Ruppert's Sweet

Grower Notes - Brix Cider

Wild apple tree discovered along a fence row in Southwest Wisconsin. Large, round apples. Eight or more bushels were harvested from the same tree two years in a row. The tree and the apples seemed healthy and mostly blemish-free, even with no care for the tree. The tree is broad and spreading. Apples have a sweet, nectar-like flavor. Apples stay on the tree and can be harvested into November. Cider apple tree with good potential due to its high yield under low maintenance and high brix when harvested late in the season.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties

No notes

Secor

Grower Notes - Albion Prairie Farm

Secor is a 1906 cross of Salome x Jonathan from Iowa State and was introduced commercially in 1922. Fruit is medium to large, roundish oblate to a bit conic, with moderately bright red skin that matures to a somewhat darker purplish red and much bloom. Flesh is very firm, crisp, fairly fine textured, rich sub-acid and of very good quality. Fruit is somewhat aromatic and lends good flavor to cider as well as being an excellent fresh eating apple. The tree is an upright-spreading grower with wide-spread branching and good healthy habit. The apples ripen in October, hang well to the tree and are purported to keep from January to March with good storage conditions. No particular problems with this variety at all.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties

Off-flavor, strong aroma, soap, wheaty, mildew

Somerset Redstreak

Grower Notes - The Cider Farm

Tall, vigorous tree producing many thin, very upright branches. Branches are hard to train. Fruit is prone to rot. Not a big cropper. Biennial. Fire blight sensitive.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties; Tasting event 3-conference

Sweet, fruity, pear, sour, clean, flat, woody, musty, bitter, drying, dusty tannin, nothing unusual, appearance cloudy (fine for that style), cloudy

St. Lawrence

Grower Notes - Cider House of Wisconsin

Yellow with red stripes and tender white flesh.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties

Boring

Steele Red

Grower Notes - Albion Prairie Farm

The name Steele Red is a synonym of several varieties. This is possibly the Massachusetts variety known as Sutton or the variety known as Red Canada (both are somewhat similar). If Sutton, this is a very nice old apple that's been around since 1757. The fruit is roundish, medium to large in size with dark, purplish-red blush over a yellowish-green ground color. The flesh is yellowish, firm, fine-textured, crisp, tender, mild sub-acid and of very good quality for dessert and kitchen use. This is not a cider variety save for its good juice flavor and aromatic qualities. No tannin structure here. This apple ripens mid-October. This variety is susceptible to cedar-apple rust and scab. This apple also blooms somewhat early and is subject to biennial bearing. The tree is an upright-spreading grower and easy to manage.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties

Tart

Stembridge Jersey

Grower Notes - Albion Prairie Farm

This is a classic cider variety from Somerset, England. Small- to medium-size fruit with some tendency to drop as it ripens. This is a bittersweet variety with firm flesh; it is a nice apple overall and worth a little trouble. This apple is grown in modern English cider orchards and makes an excellent vintage cider. Ripens late September into October. Despite several fire blight outbreaks over the years, it is not highly susceptible and can survive with preventative care.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties

Mild rose

Swaar

Grower Notes - Brix Cider

Swaar, which means “heavy” in Dutch, was first recorded in New York in 1805 but may go back further. It’s a dense apple that can stay onto the tree into winter, with increasing complexity and higher sugar content later in the season. The apples picked at Seed Savers Exchange for this project were probably picked too early (in October). The apples were large and in good condition without any sprays applied. There are a couple of Swaar trees planted in the Brix Cider orchard. After two years, they appear healthy, with moderate vigor, but have not yet produced a crop.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties; Tasting event 2-farmers and chefs

Floral, floral and tart but more to be desired, citric acid, honey, low on flavor in general, one note astringent/ bitter, bitter, bitter (alcohol), acidic and astringent—use in small amount, moderate acidity, tart up front, no flavor in the back, little sweetness but doesn’t need much, sour, sharp, heavy, drier, dry, dry but very palatable, grassy, tastes very fermented, clean/ light feel, champagne, better than others (Bergere, Oaken Pin, Chisel Jersey) but not great

Color and Mouthfeel	Strongest Attribute	Weakest Attribute
Floral, rose water color, almost colorless, light yellow, looks like white wine, light and clear, clear, clear and clean, flat and clear, a little viscous, watery, thin, but not flat, crisp, astringent, puckering, dry, bubbly and light in flavor, more bubbly than the others but still needs more	Acidic, floral notes, floral is distinctive, bitter, nice balance of acid with slight bitter, flavor intensity, tastes like a warhead, clean taste, fizziness, everything	Low flavor, no back end flavor, bland, needs more tartness, too acidic, sour, astringency, too fermented taste, needs a stronger color, color

Thornberry

Grower Notes - Albion Prairie Farm

Tall, vigorous tree producing many thin, very upright branches. Branches are hard to train. Fruit is prone to rot. Not a big cropper. Biennial. Fire blight sensitive.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties; Tasting event 3-conference

Sweet, fruity, pear, sour, clean, flat, woody, musty, bitter, drying, dusty tannin, nothing unusual, appearance cloudy (fine for that style), cloudy

Tremlett's Bitter

Grower Notes - The Cider Farm

Geneva version of Tremlett's Bitter. Tree produces a heavy crop one year and nothing the next. Easy to grow. Apples develop in clusters. Some sensitivity to fire blight. No scab.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties; Tasting event 2-farmers and chefs

Tart up front, bitter in back, weak—mild but balanced, not sweet, mild sweetness, sweet, but still dry, very subtle bitterness, bitter/sour, acidic, yeasty

Color and Mouthfeel	Strongest Attribute	Weakest Attribute
Light, light color, golden, light in texture and color, more bubbly than others, but not enough, bubbly, fizzy!, medicine feel	Balanced, sweet, acidity, tart, dryness, very sparkly, no off flavors	Beery, would benefit from florals, not sweet, too sweet

Unknown 1

Grower Notes - The Cider Farm

Vigorous. What the grower was given as scion wood may have been incorrectly identified as Ellis Bitter.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties; Tasting event 2-farmers and chefs; Tasting event 4-co-op employees

Floral, fruity, sour green apple taste, bittersweet apple, apple, pear, tart and bitter, sweet, honey, sugary, sour, dry, drying , bland, watery, characterless, boring, undertone/ hint of mild acidity, acidic, acid, metallic, wine-y, potential for single varietal

Color and Mouthfeel	Strongest Attribute	Weakest Attribute
Balanced, flat, golden, light yellow, light, clear, crisp, mild fizz	Herbal, floral, tart, sour flavor, dry, balanced flavor	Missing a round taste, color, boring

Unknown 2

Grower Notes - Albion Prairie Farm

The grower notes that what was supplied as Oaken Pin may be incorrectly identified. Oaken Pin is an English dual-purpose apple from Exmoor (c.1876), good for cider and kitchen use. Fruit is large, roundish-conic. Skin is yellow with dark orange-red streaks and a mahogany blush. The flesh is crisp, sweet, yellowish, aromatic, rich and very intense. Ripens late September into October. Adds great body and aroma to cider. The tree is moderately vigorous with no significant problems.

Hard Cider Flavor Descriptions - Tasting event 1-all varieties; Tasting event 2-farmers and chefs; Tasting event 4-co-op employees

Pear, apple, woody, astringent, very astringent, drying, bitter, slightly bitter, low bitterness, dry, like a dry white wine, whiskey, acrid, acid, acidic, not sweet, moderate sweetness, side of tongue off-flavor tending toward rubber, plastic, antiseptic, chemical-y, paper-y , flat, watery, boring, gassy, overripe

Color and Mouthfeel	Strongest Attribute	Weakest Attribute
Orange, cloudy appearance, green color, apple juice color, flat, plain finish, thin, bubbly yet heavy	Slight bitterness on finish, astringency, bubbles, not bright, watery	Lingering aftertaste, aftertaste, mouthfeel, rubbery off-flavor

Commercial checks

To gather sensory data on the apples used in this study, researchers conducted four cider tastings with tasters from different demographics. Each of the 41 ciders were tasted at least once by at least six people. Each cider was assigned a randomized three-letter code so that tasters wouldn't be influenced by the varietal names. Researchers added a commercial cider as a "check" during the blind tasting as a point of reference for desirable flavor in the data collected, and these were often rated towards the top by tasters.

Classic Dry from The Cider Farm

Hard Cider Flavor Descriptions -Tasting event 1-all varieties; Tasting event 2-farmers and chefs; Tasting event 4-co-op employees

Floral, melon, vanilla, molasses, vanilla and honey, sweet, woody, moldy, sweet at first, ends with bad taste in mouth, vinegar, dead yeast, yeasty, ester-y, gassy, watery, thin

Tremlett's Commercial from The Cider Farm

Hard Cider Flavor Descriptions - Tasting event 3-conference

Melon-y, artificial, pear, caramel, rich, bitter, acidic, full, cane sugar, geranium, a bit medicinal, tart at the finish, sparkle

All apple variety images taken by Nicholas Smith of the UW-Madison Food Science Department.