Apple Cultivar Evaluations for Cider Making in Vermont, U.S.A.

T.L. Bradshaw[1], S.L. Kingsley-Richards, and J. Foster.

University of Vermont, Burlington, VT, 05405 USA

ABSTRACT

Fermented cider production has increased rapidly in the U.S. in the past five years, which has necessitated an evaluation of apple cultivars used for cider making. Cider apples may be simply defined as any apple that is used in cider production, but the real answer is more complicated. The selection of apple cultivar is possibly of greatest concern to cidermakers for overall product quality. However, unlike in the case of grapes and wine, specific cultivars are rarely sought by the end consumer as a primary means of identifying ciders. Ciders are typically made from multiple apple cultivars, including dessert fruit as well as specialty cultivars with unique acidity characteristics and phenolic compounds that contribute complexity to the finished product. In traditional cider-producing regions in the U.K. and France, for example, specialty cultivars make up the majority of ciders produced, and are grown in separate production systems tailored to their unique horticultural characteristics which rely heavily on mechanization to make up for low fruit price. In contrast, the supply of specialty cider apples is low in the U.S., and domestic cider production relies primarily on dessert fruit cultivars culled from fresh market channels or from processing orchards. Dessert cultivars commonly-grown in Vermont generally exhibit lower levels of phenolic compounds and higher levels of malic acid than specialty cultivars. However, there is limited research on horticultural and disease susceptibility characteristics of specialty cider fruit in Vermont or surrounding regions which limits present recommendations to stakeholders for best cultivars and production systems suited to cider apple production.

Keywords: *Malus x domestica,* cultivar adoption, juice quality, cider evaluation.

INTRODUCTION

Fermented cider (hereafter referred to as 'cider') is a traditional value-added product produced by both orchardists and independent cider makers in the U.S. from the juice of pressed apples (*Malus* x *domestica*). In recent years, U.S. cider production has increased at an average rate of over 50% annually, with total revenue over US$290 million in 2014 (Petrillo, 2014). Growth in the cider industry represents increased market opportunities for fruit producers, but competition for limited supplies of fruit may present barriers for future growth of the industry. U.S. cideries use several types of apple cultivars for cider making, including dessert cultivars culled from fresh market production channels, 'dual purpose' cultivars grown for both fresh market and cider markets, and specialty cider cultivars with unique juice chemistry suited for cider making but not for traditional fresh market outlets (Merwin, et al., 2008). Industry trade articles highlight cidery concerns about potential shortages available for cider making, especially for specialty cultivars that may improve cider quality and facilitate increased product price (Frochtzwajg, 2014; Milkovich, 2014).

Vermont cideries express interest in purchasing specialty cider apples (Becot, et al., 2016), but supply is low in the state and surrounding region. A survey of Vermont growers conducted in 2011 found only 1.2% of acreage planted to 'miscellaneous heritage varieties', which may include dessert and cider cultivars (VTFGA, 2011). Plantings of cider apples have increased since then, but because competition is high for cider apples and market advantage may be substantial for early

[1] E-mail: tbradsha@uvm.edu.

Authors' archival copy. Published at: Bradshaw, T. L., Kingsley-Richards, S. L., & Foster, J. A. (2018). Apple Cultivar Evaluations for Cider Making in Vermont, U.S.A. Acta Hort, 1205, 453-460.

adopters, growers have been reluctant to publicly report specialty cider cultivar plantings, and response to a 2016 survey was so low that meaningful data could not be gleaned from it. However, new orchards of specialty cider cultivars totaling less than 20 ha out of 688 ha (3% of total) of orchards reported in the state (NASS, 2015) have been planted in the state in the past five years (data not presented).

Table 1. Classification of cider apple cultivars by juice chemistry characteristics (Lea, 2015).

	Sweets	Sharps	Bittersweets	Bittersharps
% tannin[z]	<0.2	<0.2	>0.2	>0.2
% acidity[y]	<0.45	>0.45	<0.45	>0.45

[z] Total polyphenolic compounds, w/v

[y] Malic acid equivalent, w/v

Grower reluctance to plant specialty cider apples may be attributed to several factors. First, a shortage of trees exists in the nursery trade which may limit orchard establishment for five or more years until trees can be propagated and shipped through the supply chain (W.H. Gale, pers. commun.). Even if space were available in nurseries, specific cider apple cultivar recommendations for production within fruit growing regions of the U.S. have not been developed because sound, replicated field trials assessing horticultural, disease susceptibility, and cider quality parameters have not been extensive. Many specialty cultivars originated in Europe, including western England, northwestern France, and northern Spain (Merwin, et.al., 2008). Those regions generally have a maritime climate which is dissimilar to that of the major fruit productions regions of the U.S. Native North American cultivars used specifically for cider making are typically selected from regional locations and have also not been extensively trialed across diverse production regions or production systems. A lack of specialty cultivar plantings available for use by public researchers and with sufficient tree number and replication has slowed this research. As such, recommendations to date have generally been based on anecdotal or regionally-specific observations and have been made with reservation regarding widespread planting in commercial orchards (Merwin, 2015; Moulton, et al., 2010).

While little research has been conducted on field characteristics of specialty cider apple cultivars grown in North America, juice quality of those as well as some dessert and dual-purpose cultivars have been evaluated in limited studies. One long-term research program in maritime northwest Washington State has evaluated specific cider apple cultivars for juice characteristics for over 15 years (WSUE, n.d.). The climate at that research station is maritime with warm summers, mild winters, and abundant precipitation (Köppen-Geiger climate classification Csb) and similar to many cider apple production regions in Europe. In contrast, most U.S. apple production regions are in continental climates with lower winter temperatures and summer rainfall (Dfb) Results from that program are useful in evaluating juice chemistry parameters of multiple (>50) cultivars, but lack of in-orchard replication and the uniqueness of the site's climate limit the power of the experiments and transfer of results to other fruit production regions. In New York, a two-year evaluation of juice characteristics of 31 cultivars was conducted with fruit collected from multiple orchards and production systems (Valois, et al., 2006). This research also provides useful information but again is limited in replication and consistency of production method. Another similar evaluation of 20 dessert and cider apples was conducted in Virginia (Thompson-Witrick, et al., 2014). Cider apple cultivar juice evaluations to date should be considered a developing body of research, and increased assessment over multiple years and sites will be necessary to continue to fully evaluate cultivars suitable for cidermaking across diverse regions.

Cider making quality of varietal juices produced in North America has not been extensively studied. In the maritime Washington state program, fermented ciders have been evaluated qualitatively over multiple seasons (Moulton, Miles, King and Zimmerman, 2010), and full sensory analysis has been conducted on four commercially available blended ciders but not on their single varietal components (Tozer, et al., 2015). In the latter study, tannin and specific gravity (i.e. sweetness) to acid ratio increased panelists' willingness to pay for ciders. This indicates that specific cider cultivars with acid and tannin levels suitable for cider making and/or cider making techniques that preserve sweetness in higher acid ciders may be more preferable to consumers when used in finished commercial ciders.

MATERIALS AND METHODS

Research was conducted in 2014 and 2015 growing seasons using fruit collected from Vermont orchards. In 2014, eight dessert cultivars grown for sale to cideries were evaluated in three commercial orchards from mature semi-dwarf trees with five trees selected per cultivar. Each cultivar was selected from a single orchard and direct statistical comparisons not made among cultivars. In 2015, ten specific cider or dual-purpose cultivars were evaluated from a single orchard block in Addison County with consistent soil type, management, and training system. Trees were in their fifth growing season and planted on M.9/M.111 interstem rootstock at 854 trees/ha. Data were collected from five randomly selected trees and results among cultivars compared as described below.

Juice analysis

In 2014, approximately 140 kg fruit in total was randomly selected from trees assessed in harvest evaluation for one replication per cultivar. In 2015, ten-fruit samples were randomly collected from each of five replications. In each year, fruit were selected from all areas of the tree to minimize positional differences in ripening. Juice was extracted in 2014 with a commercial bladder press (Lancman VSPI-X120, Vransko, Slovenia) and in 2015 with a Breville Juice Fountain Elite juicer (Breville USA, Torrance, CA). Juice samples were frozen until evaluation, then thawed and centrifuged prior to testing. Samples were analyzed for: sugar content (soluble solids (SS),° brix) using a PEN refractometer (Atago, Bellevue, WA); pH with a digital pH meter (Accumet AB15, Fisher Scientific, Waltham, MA), and titratable acidity (TA, malic acid equivalent) by titrating with 0.1 M sodium hydroxide to pH 8.2. Total polyphenols (tannin) and yeast assimilable nitrogen (YAN) were assessed by enzymatic assay (Total Phenols UniFLEX kit, Ammonium UniTAB Reagent kit, and Primary Amino Nitrogen UniTAB Reagent kit, Unitech Scientific, Hawaiian Gardens, CA) and analysis by spectrophotometer (Hach DR 6000, Loveland, CO). All methods used standard procedures for apple juice evaluation (Valois, et al., 2006). Because 2014 data were not replicated, results were not analyzed but are shown for general comparison purposes; 2015 data was analyzed by ANOVA using Tukey's adjustment for multiple comparisons (SAS Institute, Cary, NC).

Cider evaluation

Juice from field trials in 2014 was fermented to dryness by three commercial cideries in 19 L lots with Lalvin EC1118 yeast and Go-Ferm Protect yeast nutrient (Scott Labs, Petaluma, CA) following standard protocols with no post-fermentation processing (Lea, 2015). In March 2015, ciders were evaluated by a panel of 43 commercial cider makers and apple growers on a 0-5 hedonic scale for attributes of appearance, aroma, perceived sweetness, acidity, mouthfeel, and overall flavor. Ciders were evaluated blind and grouped by cultivar class based on tannin and acidity levels in pre-fermented juice. No cultivars from bittersweet or bittersharp cultivars were available in 2014, so varietal 'Dabinett' and mixed bittersweet ciders from a non-commercial source but fermented using the same protocols were included. In addition, each participating cidery included a finished, blended cider for evaluation. Results from participant scoring were analyzed separately within each class using non-parametric chi-square (SAS 9.2, Cary, NC) to account for differences in sample size among classes.

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RESULTS AND DISCUSSION

2014 Juice analysis and cider evaluation

All fruit cultivars collected from participating commercial orchards were categorized as 'sharp' or 'sweet' based on William's criteria (Table 2). Soluble solids (SS) for dessert fruit commonly grown in Vermont were below 13° brix, whereas dual-purpose cultivars ('Ashmead's Kernel', 'Esopus Spitzenburg', 'Wickson') identified as desirable by Vermont cideries (Becot, et al., 2016) had SS of 13.9-17.6° brix. Those cultivars also had generally higher levels of titratable acidity than commonly-grown dessert cultivars. No cultivars had sufficient tannin levels to classify as 'bitter', although 'Dabinett' had 1.6-8.4 times greater tannin levels than any other cultivar. Yeast assimilable nitrogen was below the optimum of 140-350 mg/l for fermentation for all cultivars except 'Ashmead's Kernel', but low nitrogen levels are easily and routinely corrected in the cider making process (Bisson and Butzke, 2000).

Differences were observed among varietal ciders for appearance and aroma within the sharps category and appearance, aroma, acidity, and mouthfeel within the sharp and sweet categories by tasters. While the chi-square test does not allow for mean separation among treatments, 'Ashmead's Kernel' ranked highest for appearance and aroma in the sharp category. Within the sweet category, 'Paulared' ranked highest for appearance and aroma, and 'Honeycrisp' ranked highest for acidity and mouthfeel. For all parameters, ratings were below or near neutral (rating of 3), which indicates that the single variety ciders would not likely have characteristics ideal for commercial release when fermented as dry ciders. In the bittersweet class, the blended cider ranked higher for acidity and flavor compared to 'Dabinett', which again suggests that this single cultivar does not contain ideal characteristics for a finished cider as fermented. Among the blended ciders, blend 1, which was a commercial release containing both dessert and specialty cider cultivars, ranked highest for appearance, sweetness, and flavor, and blend 2, which was not released commercially, ranked lowest. Blends 1 and 3 were finished off-dry (i.e. with detectable residual sweetness) which suggests that post-fermentation sweetening may improve cider desirability. Analysis among cider classes further confirms that post-fermentation processing and addition of high-tannin cultivars may improve cider desirability (Figure 1). Bittersweet ciders ranked highest for appearance, likely due to higher tannin content which oxidizes to produce deeper color (Lea and Drilleau, 2003). Blended ciders ranked highest for sweetness and flavor, although bittersweet ciders ranked second for mouthfeel which highlights the contribution of tannins to that characteristic. The contribution of tannin to perceived cider quality is supported by Tozer et al. (2015), although in that study, increased sweetness in commercial ciders decreased consumer willingness to pay. However, all varietal ciders in this study were dry (i.e. with no residual sugar), whereas those evaluated by Tozer et al. (2015) contained varying levels of sweetness ranging from off-dry to sweet, and excess sugar out-of-balance with cider acidity likely reduced perceived cider quality in that study.

Table 2. Juice analysis and hedonic evaluation scores for cider apples evaluated in 2014. Parameters include: soluble solids (SS), pH, titratable acidity (TA), total polyphenols (tannin), yeast assimilable nitrogen (YAN), and subjective cider evaluation criteria (Mitchell, 2009).

Class[z]	Cultivar	SS (°brix)	pH	TA (g/l)[y]	Tannin (mg / l)[y]	YAN (mg/l)	Appearance	Aroma	Sweetness	Acidity	Mouthfeel	Flavor
Sharp	Ashmead's Kernel	17.6	3.25	10.40	489	262	3.67 *[x]	3.47 *	2.63	2.97	3.03	3.17
Sharp	Esopus Spitzenburg	15.3	3.48	7.10	486	113	2.61	3.00	2.57	2.84	2.84	2.69
Sharp	Idared	10.8	3.29	5.98	343	16	2.59	2.98	2.85	2.88	2.78	2.82
Sharp	Jonagold	12.3	3.4	5.12	275	39	3.21	2.82	2.73	2.97	2.92	2.86
Sharp	Liberty	11.5	3.45	5.72	369	57	3.34	2.97	2.75	2.87	2.79	2.72
Sharp	McIntosh	11.7	3.25	5.48	408	30	2.96	2.84	2.71	2.95	2.74	2.82
Sharp	Topaz	12.4	3.35	9.86	738	16	3.13	2.90	2.35	2.69	2.54	2.41
Sharp	Wickson	13.9	3.4	11.94	147	53	3.10	2.65	2.36	2.78	2.72	2.78
Sweet	Cortland	11.2	3.43	4.74	459	45	3.27 *	2.65 *	2.63	2.93 *	2.68 *	2.46
Sweet	Honeycrisp	12.6	3.52	4.97	254	85	3.25	3.02	2.73	2.98	3.00	2.79
Sweet	Macoun	11.7	3.47	4.17	251	65	3.24	2.30	2.47	2.57	2.61	2.43
Sweet	Paulared	11.0	3.4	4.45	747	30	3.79	3.07	2.40	2.79	2.77	2.67
Bittersweet	BS Blend[w]	na[v]					3.90	2.84	2.76	2.94 *	3.19	3.13 *
Bittersweet	Dabinett	13.1	4.13	1.88	1228	61	3.81	3.19	2.59	2.55	3.00	2.39
Blend	1	na[v]					3.28 *	3.14	3.45 *	3.21	3.34	3.34 *
Blend	2						2.53	2.77	2.72	2.79	2.93	2.77
Blend	3						3.20	3.03	3.10	3.14	3.23	3.03

[z] Cider apple class based on Lea's (2015) classifications and measured parameters. Blends were commercially blended and adjusted ciders available or intended for retail sale.

[y] Titratable acidity measured in malic acid equivalents, total polyphenols measures in gallic acid equivalents.

[x] Cider quality parameters within each class highlighted with * indicate differences observed between ciders at α=0.05 using non-parametric chi-square test. Parameters were rated 1-5 for desirability in as components in blended ciders where 1=Strongly dislike and 5= Strongly like.

[w] Blend of bittersweet cultivars of European origin collected from non-commercial orchard.

[v] Juice chemistry not conducted on blended ciders prior to fermentation.

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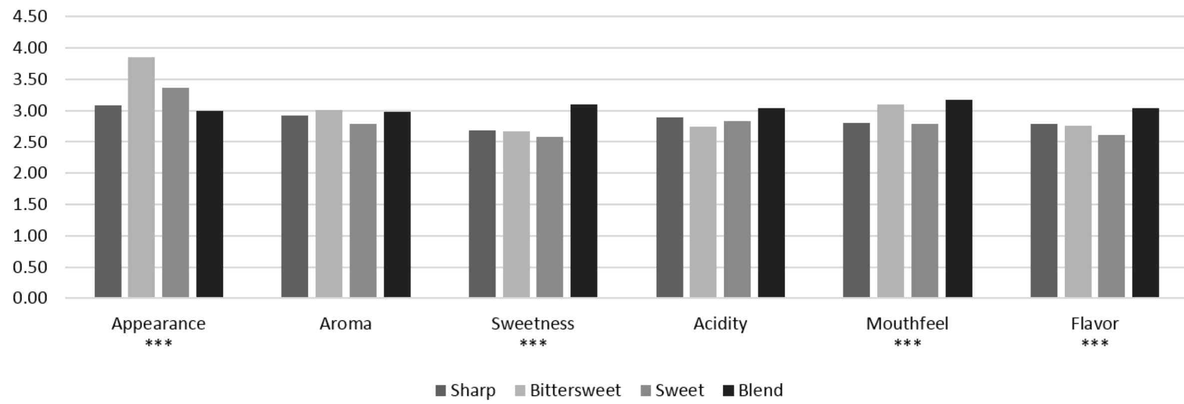

Figure 1. Hedonic evaluation of fermented single cultivar ciders and finished blends form 2014 growing season by apple class (Lea, 2015). Values represent mean of assessed parameters (1-5 scale) for all ciders within class. *** denotes significant differences for assessed parameters at α=0.05 using non-parametric chi-square test.

2015 Juice analysis

In 2015, juice was analyzed from three sets of cider cultivars (Table 3). This data represents initial results of long-term (2-3 year) evaluation of the cultivars within each lot. Lot 1 represents specialty cider apples grown in a single commercial orchard. Among the cultivars evaluated, 'Ashmead's Kernel' had among the highest SS and TA, similar to 2014 when it was compared to traditional dessert fruit grown in Vermont. The European cider cultivars 'Chisel Jersey', 'Dabinett', 'Harry Master's Jersey', and 'Yarlington Mill' and the North American cultivar 'Redfield' had among the lowest SS, although all were above minimum recommendations of 10.2 for commercial cidermaking (Lea, 2015). TA and pH were relatively well-correlated, and the European bittersweet cultivars tended to have higher pH and lower TA than the North American cultivars. High pH was observed among the European cultivars and juice from them may require blending with lower pH juice or acidification to maintain acceptable conditions for yeast to conduct fermentation (Lea and Drilleau, 2012). The cultivars into three groups with high ('Dabinett', 'Redfield', and 'Yarlington Mill'), medium ('Brown Snout', 'Chisel Jersey', 'Harry Master's Jersey') and low ('Ashmead's Kernel', 'Calville Blanc', 'Esopus Spitzenburg') tannin levels. YAN levels varied significantly by cultivar despite consistent management.

Lot 2 consists of apple scab-resistant cultivars (SRCs) grown under organic management at the University of Vermont Horticulture Research & Education Center. Although bred as dessert fruit, SRCs may have increased phenolic content compared to traditional dessert fruit (Mayr, et al., 1997) and their disease resistance makes them attractive to growers seeking low-input cultivars to reduce costs when growing fruit for cider markets. All cultivars had SS above 10.2, although 'William's Pride' had the lowest SS at 10.3. Juice pH for all cultivars ranged from 3.2-3.6, which is acceptable for cidermaking. 'Crimson Topaz' had the highest TA and 'Florina Querina', 'William's Pride', and 'Winecrisp' the lowest. Juice TA is an important characteristic to consider when blending finished ciders, especially if low TA bittersweet or high TA bittersharp cultivars are used in the blend. Tannin levels were all below the 2000 mg/l 'bitter' threshold, which may be expected for fruit bred for the dessert market. However, the total phenolic proxy measurement for tannins includes many flavonols that could contribute other characteristics beside bitterness, such as fruitiness and aroma, to ciders (Thompson-Witrick, et al., 2014). Fermentation and evaluation of these cultivars would be required to fully evaluate their potential for cider making.

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Feral apple selections were included in lot 3 to screen for promising potential cultivars for further cultivation and assessment. All selections have been used in cider blends by Vermont cideries but have not been evaluated individually for juice or horticultural characteristics. 'Franklin Cider Apple' is the only named cultivar within the lot, and has been selected for commercial propagation and plant patenting but has had little formal assessment (Herrick, 2016). Although its evaluation is preliminary, 'Franklin Cider Apple' had among the highest tannin levels of those tested in 2015, and SS of 16.9° brix. Other selections of note include MC6, MC7, MC8, and NC1 which had high tannin levels and sufficient SS for quality cidermaking.

This initial study is limited by short-term data and limited cultivar and orchard replication. Continued juice assessment over multiple seasons, horticultural evaluation in diverse orchard systems, and further evaluation of fermented ciders is necessary to develop best recommendations for cider apple production in Vermont.

Table 3. Juice analysis including soluble solids (SS), pH, titratable acidity (TA), total polyphenols (Tannins), and yeast assimilable nitrogen (YAN) for three lots of cider apples evaluated in 2015.

Cultivar	Lot[z]	SS (°brix)		pH		TA (g/l)[y]		Tannins (mg /l)[y]		YAN (mg/l)	
Ashmead's Kernel	1	18.0	a[x]	3.0	d	10.8	a	667	c	166.3	a
Brown Snout	1	18.2	a	3.8	c	4.1	d	2148	b	97.4	bc
Calville Blanc	1	15.3	b	3.1	d	10.0	ab	728	c	86.3	cd
Chisel Jersey	1	13.1	bc	4.1	b	1.5	e	2408	b	55.4	d
Dabinett	1	13.1	bc	4.2	ab	1.1	e	3656	a	31.8	de
Esopus Spitzenburg	1	15.8	ab	3.1	d	9.3	b	633	c	112.7	b
Harry Master's Jersey	1	12.0	c	4.3	a	1.2	e	2120	b	36.7	cd
Redfield	1	13.6	bc	3.2	d	6.5	c	3268	a	58.6	c
Yarlington Mill	1	12.2	c	3.8	c	1.7	e	3538	a	8.9	e
Crimson Crisp	2	14.2	ab	3.4	b	8.3	b	1089	a	137.2	b
Crimson Gold	2	13.8	ab	3.4	b	7.9	bc	702	ab	97.1	bc
Crimson Topaz	2	14.0	ab	3.2	c	12.1	a	617	ab	167.5	ab
Florina Querina	2	14.1	ab	3.5	ab	6.3	c	556	ab	131.8	b
Galarina	2	14.9	ab	3.5	b	8.7	bc	668	ab	234.5	a
Liberty	2	13.0	b	3.2	bc	8.5	bc	1049	a	117.4	b
Williams Pride	2	10.3	b	3.4	b	5.5	c	439	b	56.2	c
Winecrisp	2	16.2	a	3.6	a	6.1	c	595	ab	68.8	bc
Franklin Cider Apple	3	16.9		2.8		7.8		3557		28.4	
MC1	3	9.3		2.9		9.0		2236		26.7	
MC2	3	11.2		3.3		4.2		1215		18.0	
MC6	3	15.1		4.4		1.6		1884		41.1	
MC7	3	11.3		3.1		8.7		2335		27.0	
MC8	3	13.3		3.2		10.5		1801		39.7	
NC1	3	12.9		4.4		1.4		2367		34.6	
NC2	3	14.2		3.3		5.8		1151		74.2	

[z] Lot 1 = fruit replicates (n=5) collected from one orchard in Addison County, VT; lot 2 = fruit replicates (n=5) collected from one orchard in Chittenden County, VT; lot 3 = single samples (n=1) of promising wild apple cultivars collected from Franklin and Washington Counties, VT.
[y] Titratable acidity measured in malic acid equivalents, total polyphenols measures in gallic acid equivalents.
[x] Values represent mean for of all replicated for lots 1 & 2, and single values for lot 3. Values followed by the same letter within each lot do not differ at α=0.05 using Tukey's adjustment for multiple comparisons.

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ACKNOWLEDGEMENTS

This research is funded by Vermont Working Lands Enterprise Initiative #02200-WLEB-77USDA "Apple Market Optimization and Expansion through Value-Added Hard Cider Production", USDA Federal-State Marketing Improvement Program (FSMIP) Grant #11677750 "Orchard Economic Assessment to Support Vermont Hard Cider Production", Vermont Hard Cider Company, Vermont Tree Fruit Growers Association, and Vermont Agriculture Experiment Station.

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