Can Cider Chemistry Predict Sensory Dryness? Benchmarking the Merlyn Dryness Scale

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Abstract

The growing popularity of hard cider in the United States has been accompanied by an inconsistent understanding of the nature and importance of consumers' perception of dryness and sweetness in the product. In 2018, the New York Cider Association proposed the Merlyn Dryness Scale as a tool to predict cider dryness using basic cider chemistry, but this approach has yet to be validated in sensory experiments. In the current study, panelists (N = 48) evaluated three different commercial ciders served at two different temperatures (2 °C and 22 °C) in three parts: by rating the dryness of the sample on a line scale equivalent to the range of the Merlyn Dryness Scale, by using a simple check-all-that-apply (CATA) tool that included dryness, and by rating their overall liking on a 9-point hedonic scale. The results indicated that the Merlyn Dryness Scale may not achieve its goal of predicting perceived dryness in cider, as consumers perceived cider samples to be more dry than was suggested using Merlyn Scale chemical procedures. Contrary to expectations, the serving temperature of the cider samples did not significantly impact perceived dryness rating but did influence overall liking. This study suggests that predicting sensory dryness from cider-chemistry parameters requires further study.

Key Words: Hard Cider, Sensory, Merlyn Dryness Scale, Dryness, Check-All-That-Apply (CATA), Consumer Liking

1. Introduction

Cider, often called hard cider in the United States, is an alcoholic beverage made from fermenting apple juice. Cider has been experiencing a resurgence in popularity since the turn of the century (1,13,14,18,23). However, overall growth of the cider industry is thought to be hampered by inconsistent marketing and product information about the flavors of cider, among other factors (7,8). The American Cider Association (ACA), hard cider's leading industry trade group, has attempted to develop guidelines for more consistent cider descriptions particularly related to dryness and sweetness (21). One approach, which has been successful for Riesling wines, is to provide consumers with relative sweetness and dryness of the product using numeric scales (30). In cider, dryness and sweetness scales could be useful sensory predictors for consumers who are motivated by taste when making purchase decisions (36)**.**

Recently, the New York Cider Association (NYCA) proposed a dryness-sweetness scale called the Merlyn Dryness Scale (24,25). This scale views dryness and sweetness on a bipolar scale as opposite sensations (*Figure 1*). The scale is based on the International Riesling Foundation's scale for describing the sweetness and dryness of Riesling wine (24). The Merlyn Dryness Scale classifies cider sweetness by measuring the ratio of a given cider sample's residual sugar and titratable acidity, and then adjusting the ratio by quarter-unit or half-unit increments based on total polyphenol content, all on an anchored scale (*Figure 1*). For example, if polyphenol content is < 500 ppm, the numerical RS/TA ratio remains unadjusted; if polyphenol content is 500 to 750 ppm, the RS/TA ratio is reduced by ¼ of a unit; if polyphenol content is 750 to 1000 ppm, the RS/TA ratio is reduced by ½ of a unit; if polyphenol content is >1000 ppm, the RS/TA ratio is reduced by ¾ of a unit (26).

This method is intended to account for the ways in which acidity and bitterness can impact the dryness perception of a beverage (9,12,20,34). However, ethanol content can also impact dryness-sweetness sensations, and which may impact the effectiveness of the Merlyn Dryness Scale (9,27). Though trained cider professionals piloted the Merlyn Scale at the ACA's

annual CiderCon conference in 2018 and 2019 (25), the Merlyn Scale has not yet been used in more standardized sensory testing situations with ordinary cider consumers. Piloting the Merlyn Dryness Scale with untrained consumers may be relevant for shedding light on the scale's real world validity (2,4,10,31).

To date, there are multiple methods of measuring polyphenol content in wine and cider (5,6,17,19), but no conclusive evidence to suggest that one method of quantifying polyphenol content most accurately matches sensory evaluations of bitterness and astringency. This has direct implications on the effectiveness of measured polyphenol content as a proxy for bitterness for adjusting a sensory dryness-sweetness scale. Furthermore, cider can be served at varying serving temperatures, and research with wine suggests that serving temperature can affect sweetness perception (32), so assessing the impact of serving temperature on dryness perception may also affect the scale's validity.

This study piloted the Merlyn Dryness Scale chemical methods with three cider products served at different temperatures and evaluated by an untrained consumer panel. The goal of this study was to investigate the validity of the scale and the effect of serving temperature on dryness-sweetness perception in American cider. As a secondary objective, the research also gathered preliminary evidence of sensory attributes and preferences related to dryness and sweetness.

2. Materials and Methods

2.1 Sensory Evaluation

Cider consumers (N = 48) were recruited from the Virginia Tech and surrounding Blacksburg, Virginia communities. The research study was approved by Virginia Tech's Institutional Review Board (IRB #21-234), and panelists were not financially compensated for participation.

Three hard ciders selected for this study were from Virginia, New York, and Vermont (*Table 2*), and chosen because they had a dryness/sweetness scale depicted on their packaging or on the producer's website. The chosen cider samples were described as semi-dry (Eden), semi-sweet (Buskey), and a 1.5/5 rating (i.e., very close to extreme dryness, 1911 Est.). While these ratings do not cover the full diversity of dryness-sweetness ratings, they were chosen because they did utilize dryness-sweetness scales and terminology and because the cider samples were locally available and fit within financial constraints of the project, primarily in regards to the sample procurement and the chemical analyses. Cider samples were purchased from Vintage Cellar (Blacksburg, VA).

Subjects tasted all 3 ciders in randomized, sequential, monadic order, served both at room (22 ºC) and refrigerated (2 ºC) temperatures for a total of 6 samples. Cider samples (1.5 ounces) were served in black, opaque wine glasses. Once opened, the canned samples were transferred to a 1 L airtight bottle to prevent loss of carbonation. Samples were returned to the refrigerator when not in use, and samples were discarded and new samples were poured after 3 hours holding time.

Sensory testing took place in Virginia Tech's Sensory Evaluation Lab. All samples were served in individual booths with white light. For each sample, participants were asked to (1) rate the cider sample for perceived dryness on a structured line scale, (2) check all attributes that apply (CATA) to the cider sample, and (3) rate their hedonic liking of the cider sample on a 9-

point hedonic scale. Affective testing was conducted to further investigate evidence that dryness and sweetness is related to consumer liking (28). The dryness-sweetness scale used during evaluation was identical to the Merlyn Dryness Scale: a structured line scale with four unit-markers, four descriptive spaces (dry, semi-dry, semi-sweet, sweet), and ¼ unit increments (*Figure 1)*. When rating dryness/sweetness on the scale, panelists were able to select anywhere on the line scale. Descriptive terms chosen for CATA were closely adapted from terms previously validated (15,28), see *Table 1*. The order of terms in the CATA task were the same for all cider samples to minimize the time that the task takes (16), and because term order has been shown to have minimal influence on consumer response (3). All tests were designed and completed in Compusense Cloud sensory management software (Guelph, ON). Participants were provided with crackers, water, and a spit cup with each cider sample, and were required to expectorate all cider samples in the spit cup. Participants were given 30 seconds in between samples to avoid sensory fatigue.

2.2 Chemical Analyses

The following chemical analyses were performed with the same three cider samples used in the sensory evaluation: pH, titratable acidity (TA), residual sugar (RS), total polyphenol content, malic acid (MA) and CO_2. All cider samples were tested in triplicate. The pH, TA, RS, MA and CO_2 were all completed at the same time and the triplicate measurements came from three different cans. The polyphenols were measured using an additional can of each cider on a different day. The pH was measured using a pH meter (AOAC Method 960.19) for all cider samples. Titratable Acidity was expressed in malic acid (g/L) because it is the dominant acid present in apples and hard cider (AOAC Method 962.12). Malic acid (g/L) was determined with an enzymatic assay (AOAC Method 993.05), using a microplate assay kit from Megazyme (Malic Acid Assay Kit, Megazyme International, Wicklow, Ireland). Residual sugar was assessed using an enzymatic kit from Megazyme (AOAC Method 985.09). Only fructose and glucose were measured because they are both reducing sugars. CO_2 was determined for all cider samples using the Anton Paar CarboQC (PBA, Package Beverage Analyzer), which measures dissolved oxygen by volume expansion in g/L.

The Folin-Ciocalteu (F-C) method was used to quantify the total polyphenol concentration in the ciders, as recommended for the Merlyn Dryness Scale (25). The F-C method was adapted from (33), the F-C method uses 0.2N F-C reagent, 7.5% saturated sodium carbonate anhydrous (Na_2CO_3) and 0.1% Gallic Acid (GA) stock solution. All reagents were purchased from Sigma-Aldrich (St. Louis, MO, U.S.A.). Gallic Acid stock solution was used as the standard with DI water (0.0, 0.1, 0.2, 0.3, 0.4, 0.5 g/L). Gallic Acid stock solutions (at varying dilutions) and 100uL of each cider sample were added to individual cuvettes, in triplicate (for a total of 18 test solutions). 2.5 mL of F-C stock solution and 2.0 mL of Na_2CO_3 stock solution were added to each cuvette containing the cider samples and GA stock solutions. Samples were vortexed and capped, then left to rest for 2 hours at room temperature. The samples were then vortexed again and the absorbance was read to 765nm using a PE Lambda 3A spectrophotometer.

Due to limited quantities of product, two cans of 1911 Est. cider samples were used for all chemical tests in triplicate, and CO_2 was tested in duplicate. Three cans of Eden and Buskey cider samples were used for all chemical tests and CO_2 measurements in triplicate (using one can of product for all tests, for one replicate). All chemical analyses were expressed as mean (between replicates) $\pm$ the standard deviation.

2.3 Statistical Analysis

All statistical analyses were carried out using R Statistical Software (R Core Team, 2020). To calculate sweet-dryness ratings using the Merlyn Dryness Scale chemical method (26), the ratio of average residual sugar to average titratable acidity was calculated for each cider sample. This ratio was plotted on the Merlyn Dryness Scale, and any adjustments were made based on polyphenol concentration as required by the method. For example, a cider sample with 10 g/L residual sugar and 4 g/L TA would have an initial Merlyn Dryness Scale rating of 2.5; if the sample had 500 GAE/L, then the rating would have been adjusted down the scale by ¼ unit, making the final Merlyn Dryness Scale rating 2.25. To calculate the sweetness-dryness ratings of the cider samples based on sensory data, all sweetness-dryness ratings were averaged for each cider product. Units on the sensory dryness-sweetness scale ranged from 0.0 (*'dry'*) to 4.0 (*'sweet'*); identical to that of the Merlyn Dryness Scale chemical methods.

Analysis of Variance (ANOVA) was used to evaluate the effect of product variables on perceived sensory dryness-sweetness, Merlyn Dryness Scale chemical ratings, and liking. A linear regression model was conducted to confirm the relationship between Merlyn Dryness Scale chemical ratings and liking. In order to explore the relative importance of cider chemistry and sensory attributes on perceived sensory dryness-sweetness, a Regression Tree was fitted to the entire dataset to predict rated dryness from all other measured variables.

3. Results and Discussion

Results of all chemical analyses for total residual sugar, titratable acidity, polyphenols (ppm), malic acid, and CO_2 can be found in *Table 3*, and all Merlyn Dryness ratings using both chemical analyses and sensory analyses are shown in *Table 4*. Based on chemical analyses, all cider samples should be placed beyond the far right endpoint on the Merlyn Dryness Scale, suggesting that all samples should be classified as extremely '*sweet*' (*Table 4*). In contrast, average sensory analyses classify the 1911 Est. cider as a '*semi-sweet*' cider, and the Buskey and Eden ciders as '*semi-dry'* ciders. Average dryness-sweetness ratings based on sensory evaluation ranged from 1.81 to 2.16 (*Table 4*). ANOVA testing revealed that cider product identity was the only factor to have a significant effect on dryness rating ($F(2,94) = 4.51$, $p < 0.05$). Post-hoc (Tukey's Honestly Significant Difference) testing revealed that the 1911 Est. cider was rated significantly higher ('*sweeter*') than the Eden and Buskey ciders. There was no significant variation among the panelists for dryness-sweetness ratings ($F(47,94) = 1.24$, $p > 0.05$), suggesting that even untrained consumers were capable of consistently rating cider dryness-sweetness without extreme variation. Lastly, non-significant variation in cider dryness-sweetness ratings by temperature and by panelists revealed that temperature did not affect dryness-sweetness ratings using the Merlyn Dryness Scale. Altogether, these results suggest that the Merlyn Dryness Scale's chemical procedures for defining dryness-sweetness for a small sample set of ciders may not reliably match sensory evaluations of dryness-sweetness.

It is important to note that none of the cider samples in this study had a high enough polyphenol concentration to require adjustment of dryness-sweetness rating on the Merlyn Dryness Scale. Cider can have polyphenol concentrations that range from 200 mg gallic acid equivalents (GAE)/L to over 3000 mg GAE/L (29,35), and polyphenols can contribute a bitter taste or drying sensations which can impact dryness-sweetness perception (9,12,17,20,34). Ethanol content can also impact dryness-sweetness perception (9,27), and all three cider samples used in the present study had fairly similar residual sugar and alcohol levels (between 15 and 21

g/L of residual sugar, less than 6.5% ABV). This is to suggest that the Merlyn Dryness Scale chemical methods may be more reliable in ciders with lower sugar content. As well, more research exploring the effects of alcohol on sweetness-dryness perception may be pertinent. High sugar content is also known to mask bitter and other flavors (11,22); considering this, sugar could also mask the nuanced flavors in cider that can come from different apple varieties and processing conditions, which may contribute to sensory perceptions of dryness. Thus, the Merlyn Dryness Scale or other chemistry-based approaches may apply better to ciders that have polyphenol content over 500ppm and/or those ciders with a lower ratio of sugar to acidity. Future research should assess a larger sample set of ciders with diverse chemical features in order to obtain a better understanding of how ciders can be classified and described more clearly, especially pertaining to dryness-sweetness.

In regards to the affective sensory tests, a three-way ANOVA (product x temperature x panelist) found significant differences in the liking ratings of the cider samples ($F(2,94) = 26.72$, $p < 0.05$), significant differences in the liking ratings of the different serving temperatures ($F(1,94) = 4.32$, $p < 0.05$), and significant differences in use of the scale among the panelists ($F(47,94) = 2.88$, $p < 0.05$). Results of the linear regression model of dryness ratings and liking revealed significant variation in dryness ratings across different liking ratings ($\beta = 0.64$, $p < 0.05$), indicating that assessment of dryness is explained in some part by consumers' hedonic response to the cider. However, because the present study was limited in the number of consumer panelists, more research regarding consumer preferences of sensory dryness-sweetness in cider will be critical for drawing broader conclusions for the cider industry in the US.

A Regression Tree approach (*Figure 2*) reveals how all other measured variables in this study predict sensory dryness-sweetness ratings. The first and second branches on the regression tree indicate whether a panelist checked '*dry*' or '*sweet*' in the CATA assessment was the primary driver of dryness-sweetness ratings on the Merlyn Scale. This suggests that untrained consumers are better predictors of the sensory dryness of a cider than cider chemistry. However, cider chemistry (Residual Sugar) was found to be a significant predictor of dryness at a lower branch in the Regression Tree (see *Figure 2*). Overall, the regression tree reveals that both "subjective" sensory descriptors and cider chemistry can be valuable for describing the dryness-sweetness of cider products, in comparison to a bipolar scale.

It is important to also note the limitations of this study. Firstly, only three cider products were chosen for use in this initial study due to financial constraints. Within the context of the full range of ciders available globally, the three samples evaluated in this project were fairly similar in terms of chemical composition and packaging. While it may be relevant to explore the use of the Merlyn Dryness Scale chemical procedures using a more diverse sample set of global ciders and even using cider products that represent the ends of the scale (i.e. samples that are very sweet and very dry), the present study aimed to investigate the Merlyn Dryness Scale's effectiveness in calculating the dryness-sweetness of cider products readily available in the North American cider marketplace. The present study thus indicates that the chemical methods described by the Merlyn Dryness Scale may not accurately predict sensory dryness-sweetness perception for all American cider products. Future research may seek to develop a new methodology for consistently and effectively predicting sensory dryness-sweetness using analytical approaches. Future sensory science-focused research may also seek to confirm the effectiveness of descriptive terms in conveying the dryness-sweetness of American cider products, and more fully investigate the effects of serving temperature on the sensory perception of cider products.

4. Conclusion

Overall, these results suggest that the Merlyn Dryness Scale chemical procedures may not be an accurate predictor and descriptor of cider sensory dryness for all cider products. Untrained cider consumers appear to be consistent with their dryness-sweetness ratings for a limited number of cider products. Descriptive sensory terms may also be useful tools for describing the sensory quality of cider products, in addition to dryness-sweetness. Of note, cider dryness-sweetness may be a relevant driver of liking with cider products among consumers. Lastly, serving temperature does not have a significant effect on cider dryness-sweetness. Further research is needed to determine how the Merlyn Dryness Scale chemical procedures can reliably describe the dryness-sweetness of a larger range of cider products among a larger sample of untrained cider consumers. Future research can seek to better understand all drivers of liking for hard cider and to develop a more expansive descriptive language for American cider products.

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Data Availability Statement: Data and code are available from the corresponding author upon reasonable request.

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Table 1. CATA Attributes adapted from previous research (15,28)

Fresh Apples	Fermented	Herbal
Dry	Spice	Fruity
Smooth	Alcohol	Light
Sweet	Woody	Berries
Sour	Funky	Full-bodied
Metallic	Floral	Candy
Bitter	Putrid	Earthy
Synthetic		

Table 2. Descriptions of hard cider samples used (Manufacturer, Cider Product, % ABV, and Dryness Rating that was found on the packing or manufacturer's website).

Manufacturer	**Location**	**Cider Product**	**ABV (%)**	**Dryness Rating on Packaging or Website**
Eden Specialty Ciders	Newport, Vermont	Peak Bloom	6.2	Semi-Dry
Buskey Cider	Richmond, Virginia	RVA Cider	5.5	Semi-Sweet
1911 Established	Lafayette, New York	Original	5.5	⅙ on Sweetness Scale

Table 3. Chemical Analysis Completed on Ciders. Each of the analyses were completed in triplicate and reported as mean ± the standard deviation.

Cider Product	**pH**	**TA (g/L)**	**CO_2 (g/L)**	**Malic Acid (g/L)**	**Residual Sugar (g/L)**	**Polyphenol (ppm)**
Eden Peak Bloom	3.69 ± 0.02	4.27 ± 0.13	4.54 ± 0.02	3.62 ± 0.05	15.67 ± 0.58	203.56 ± 1.28
Buskey RVA Cider	3.94 ± 0.01	3.01 ± 0.03	4.14 ± 0.01	2.05 ± 0.14	18.67 ± 0.58	245.57 ± 8.13
1911 Est. Original	3.57 ± 0.02	4.97 ± 0.12	4.54 ± 0.00	5.63 ± 0.09	21 ± 1.00	256.86 ± 7.80

Table 4. All chemical measurements needed for the Merlyn Dryness Scale and Merlyn Dryness Scale ratings by chemical and sensory analyses for each cider. The Merlyn Scale rating for the chemical analyses each cider has a polyphenol content below 500pm indicating the ciders were not adjusted on the Merlyn Dryness Scale beyond the RS/TA ratio. The Merlyn Dryness Scale ratings by sensory analysis was reported in means and standard deviation based on the cider samples serving temperature.

	Merlyn Dryness Scale Ratings			
Cider Sample	**Based on Averages from Chemical Analysis**	**Based on Averages from Sensory Evaluations**		
		Chilled (2 ºC)	**Room Temperature (22 ºC)**	**Overall Average**
Eden Peak Bloom	4.37	1.76 ± 1.00	1.90 ± 0.94	1.83
Buskey RVA Cider	5.06	1.76 ± 0.83	1.86 ± 0.89	1.81
1911 Est. Original	4.23	2.32 ± 0.80	2.01 ± 0.99	2.16

Figure 1.

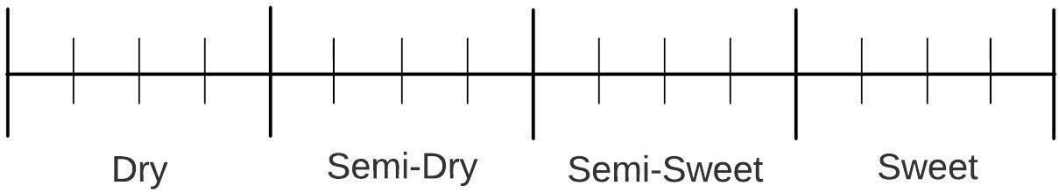


Figure 2.

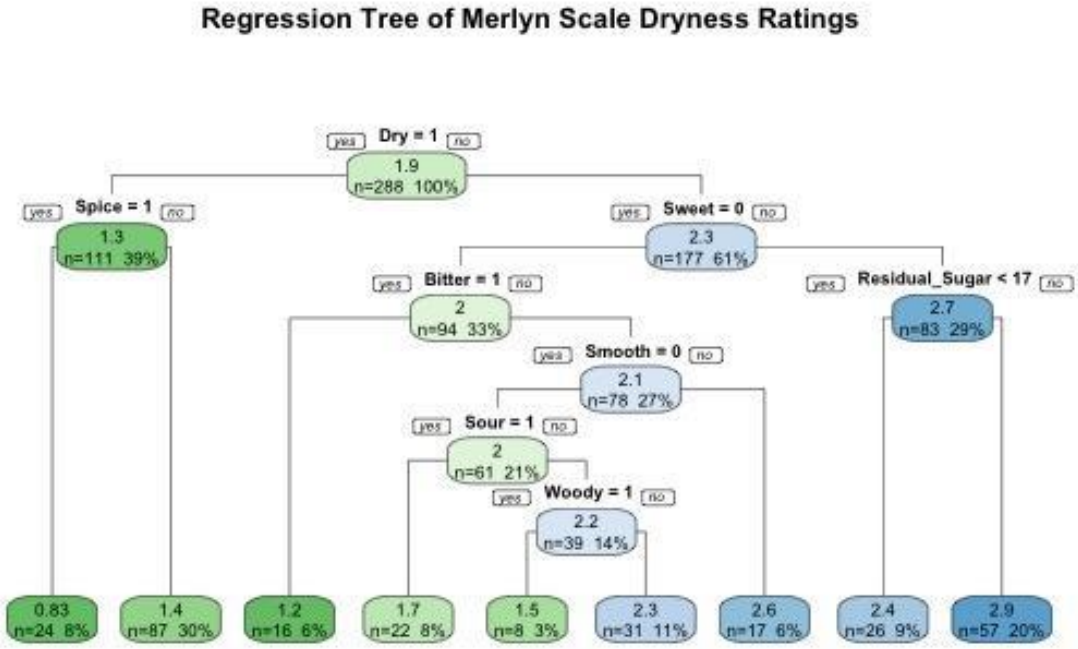


Figure 1. Merlyn Dryness Scale from NYCA, with quarter-unit increments.

Figure 2. A Regression Tree for sensory dryness based on CATA attributes, overall liking, and cider chemistry for the Merlyn Dryness Scale. The Regression Tree shows other factors in this evaluation that can be used to predict dryness-sweetness ratings on the Merlyn Scale, while ignoring interaction effects. In the Regression Tree, the top node indicates a Merlyn Dryness rating of 1.9, followed by two branches: for a given Merlyn Dryness rating of 1.9, the '*Dry*' box

in the CATA evaluation was either checked (Dry = 1) or unchecked (Dry = 0). In the Regression Tree nodes, n equals the possible sample size of a test result; for example, the top node (Dry =1) had 288 evaluations. Subsequently, the following node (Spice=1) indicates Dry being checked and Spice being checked happened in n=111 sample evaluations. When the '*Dry*' attribute was checked, the next likely attribute to also be checked in the CATA evaluation by the majority of panelists was '*Spice*'. When '*Dry*' was not checked in the CATA evaluation, the next most related attribute to '*Sweet*', unchecked (Sweet = 0). Green nodes of the plot are most related to sensory dryness and blue nodes of the plot are most related to sensory sweetness. Results of the Regression Tree reveal that sensory descriptors and cider chemistry can be useful for describing the sensory dryness-sweetness of cider products, in comparison to a bipolar scale.

Table

Table 1. CATA Attributes adapted from previous research (Kessinger et al., 2020; Phetxumphou et al., 2020)

Fresh Apples	Fermented	Herbal
Dry	Spice	Fruity
Smooth	Alcohol	Light
Sweet	Woody	Berries
Sour	Funky	Full-bodied
Metallic	Floral	Candy
Bitter	Putrid	Earthy
Synthetic		

Table 2. Descriptions of hard cider samples used (Manufacturer, Cider Product, % ABV, and Dryness Rating that was found on the packing or manufacturer's website).

Manufacturer	**Location**	**Cider Product**	**ABV (%)**	**Dryness Rating on Packaging or Website**
Eden Specialty Ciders	Newport, Vermont	Peak Bloom	6.2	Semi-Dry
Buskey Cider	Richmond, Virginia	RVA Cider	5.5	Semi-Sweet
1911 Established	Lafayette, New York	Original	5.5	⅙ on Sweetness Scale

Table 3. Chemical Analysis Completed on Ciders. Each of the analyses were completed in triplicate and reported as mean ± the standard deviation.

Cider Product	**pH**	**TA (g/L)**	**CO_2 (g/L)**	**Malic Acid (g/L)**	**Residual Sugar (g/L)**	**Polyphenol (ppm)**
Eden Peak Bloom	3.69 ± 0.02	4.27 ± 0.13	4.54 ± 0.02	3.62 ± 0.05	15.67 ± 0.58	203.56 ± 1.28

Buskey RVA Cider	3.94 ± 0.01	3.01 ± 0.03	4.14 ± 0.01	2.05 ± 0.14	18.67 ± 0.58	245.57 ± 8.13
1911 Est. Original	3.57 ± 0.02	4.97 ± 0.12	4.54 ± 0.00	5.63 ± 0.09	21 ± 1.00	256.86 ± 7.80

Table 4. All chemical measurements needed for the Merlyn Dryness Scale and Merlyn Dryness Scale ratings by chemical and sensory analyses for each cider. The Merlyn Scale rating for the chemical analyses each cider has a polyphenol content below 500pm indicating the ciders were not adjusted on the Merlyn Dryness Scale beyond the RS/TA ratio. The Merlyn Dryness Scale ratings by sensory analysis was reported in means and standard deviation based on the cider samples serving temperature.

	Merlyn Dryness Scale Ratings			
Cider Sample	**Based on Averages from Chemical Analysis**	**Based on Averages from Sensory Evaluations**		
		Chilled (2 ºC)	**Room Temperature (22 ºC)**	**Overall Average**
Eden Peak Bloom	4.37	1.76 ± *1.00*	1.90 ± 0.94	1.83
Buskey RVA Cider	5.06	1.76 ± 0.83	1.86 ± 0.89	1.81
1911 Est. Original	4.23	2.32 ± 0.80	2.01 ± 0.99	2.16

Figure 1

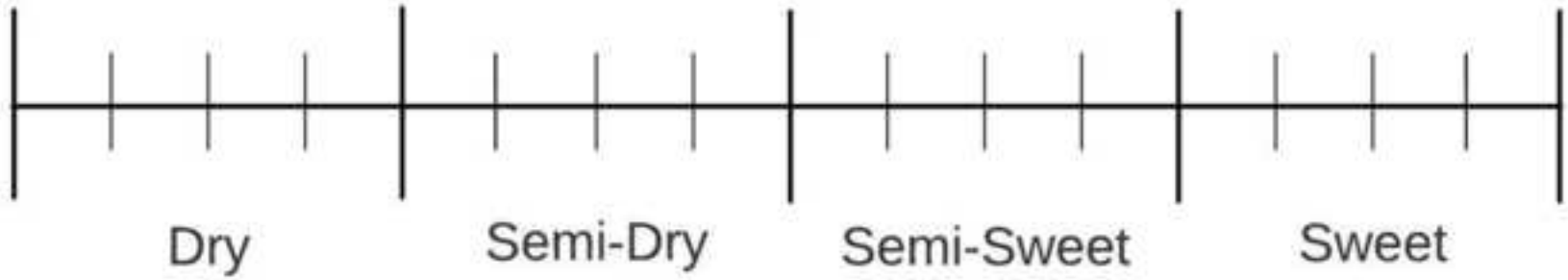
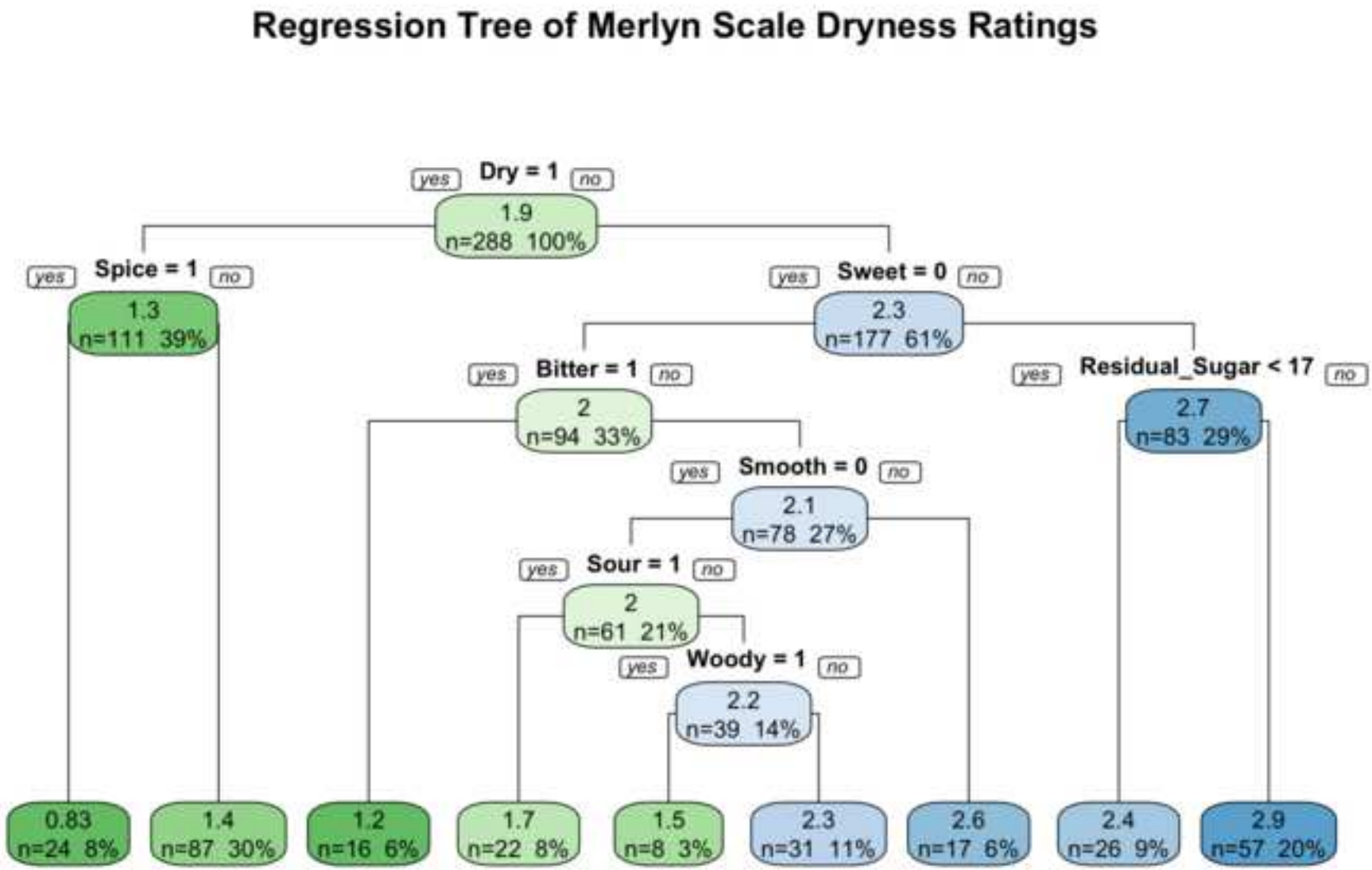


Figure 2


Regression Tree of Merlyn Scale Dryness Ratings
yes
Dry = 1
no
1.9
n=288 100%
yes
Spice = 1
no
1.3
n=111 39%
yes
Sweet = 0
no
2.3
n=177 61%
yes
Bitter = 1
no
2
n=94 33%
yes
Residual_Sugar < 17
no
2.7
n=83 29%
yes
Smooth = 0
no
2.1
n=78 27%
yes
Sour = 1
no
2
n=61 21%
yes
Woody = 1
no
2.2
n=39 14%
0.83
n=24 8%
1.4
n=87 30%
1.2
n=16 6%
1.7
n=22 8%
1.5
n=8 3%
2.3
n=31 11%
2.6
n=17 6%
2.4
n=26 9%
2.9
n=57 20%