# Appeal of the Apple: Investigating Preference, Perception, and Communication Around Hard Cider in the Northeast and Mid-Atlantic United States

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ABSTRACT

Alcoholic or “hard” cider, as it is known in the United States, is experiencing a resurgence in popularity worldwide, but most relevantly throughout the Northeast and Mid-Atlantic regions of the United States. Cider has a rich history of being America’s drink of choice, beginning with the native apple trees of indigenous communities and the proliferation of apple growing in the original American colonies. Today, cider is becoming popular particularly in the Northeast and Mid-Atlantic where New York, Virginia, and Vermont are the 1st, 8th, 12th ranked states with the most cideries in America. In light of the American cider industry experiencing such a renaissance, leading industry stakeholders and various other scholars have drawn attention to the need for increased clarity regarding consumer and producer perceptions of cider quality, as well as a more comprehensive understanding of cider sensory quality. This dissertation utilizes qualitative research methods, including focus groups and interviews conducted in New York, Virginia, and Vermont, to explore consumer and producer preferences of cider and the cider-drinking experience. In addition, this research employed traditional sensory descriptive analysis (DA) to quantify sensory differences across cider products. Lastly, this research presents findings on the use of biterm topic modeling (BTM), an emergent method of text mining for small datasets, to explore topics of discussion in cider marketing materials for products in the American cider marketplace.

This dissertation presents evidence of preferences, sensory perception, and discourse within a snapshot of the current American cider industry. Cider consumers and producers prioritize flavor when discussing cider quality, but also value how cider is made and where it comes from. Consumers, in particular, are nostalgic about the cider-drinking community and culture that is omnipresent in the Northeast. Secondly, the sensory quality of ciders can be discriminated across multiple variables, including region of origin, packaging, and style; suggesting that the sensory space of American cider products is diverse and nuanced. Lastly, when marketing cider products through website platforms, cider producers tend to emphasize topics related to sensory attributes, production elements, food-pairing, flavorings, and apple varieties. With a greater understanding of consumer and producer preferences of cider, cider sensory quality, and cider communication, industry actors and stakeholders may have a more actionable understanding of where the cider industry may be headed with continued growth. As well, this dissertation provides a framework for the use of qualitative and text mining tools to better understand facets of consumption and production, as well as marketing language in the food and beverage space.

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GENERAL AUDIENCE ABSTRACT

Cider, the alcoholic beverage made from fermented apple juice, is experiencing a resurgence in popularity worldwide, but primarily throughout the Northeast and Mid-Atlantic regions of the United States. Cider has a rich history of being America's drink of choice, beginning with the native apple trees of indigenous communities and the proliferation of apple growing in the original American colonies. Today, cider is becoming very popular in the Northeast and Mid-Atlantic where New York, Virginia, and Vermont are the 1st, 8th, 12th ranked states with the most cideries in America. In light of the American cider industry growing, there is a need for increased clarity regarding what people like about cider, as well as a better understanding of how cider can taste, beyond just sweet and "apple-y." This dissertation investigates what people like about cider and the cider-drinking experience compared to other alcoholic beverages, how cider tastes, and the language that is used to market cider products on the internet. Findings from this research indicate that taste is the most important quality determining whether someone likes or dislikes cider products; but, people are also interested in learning about how cider products are made and where they come from. Ciders made in the US are diverse in their flavors, and most cider products fall into either a fruity and sweet category, a sour and citrusy category, or a funky category. And, cider flavor can be noticeably different depending on a cider product's packaging, style, or state of origin. Lastly, when marketing cider products through website platforms, cider producers most often mention sensory terms, production-related terms, and food-pairing. Results of this research improve our understanding of cider quality and the cider industry, and methods utilized to conduct this research can serve as a framework for better understanding consumption, production, and product marketing in the whole food and beverage space.

# Dedication

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# Chapter 1 – Introduction and Literature Review

## *Introduction*

Hard cider is an internationally popular alcoholic beverage made from fermented apple juice. In the United States (US), particularly in the Northeast and Mid-Atlantic US, cider consumption has increased dramatically in recent years. From 2007 to 2017, hard cider saw a 22-fold increase in production (Alcohol and Tobacco Tax and Trade Bureau, 2017; Peck & Knickerbocker, 2018). In recent years, the cider industry has grown an average of 6.1% annually (Lombardo, 2020; Wood, 2022), and revenues are expected to continue to grow in future years. At the same time, however, consumer preferences for cider and many other food and beverage products are changing – consumers are shifting their values and consumption habits to cater to regionally, ethically, and sustainably made food (Craine et al., 2022; Lahne & Trubek, 2014; Paxson, 2013; M. Smith et al., 2021; Trubek, 2008). These shifting consumer preferences are believed to be partly contributing to a brief lull in cider popularity in the US (Fabien-Ouellet & Conner, 2018; Wood, 2022), alongside inconsistent and unclear messages regarding cider sensory quality and style standards (Demmon, 2019; McGrath, 2019). In addition, the North American cider industry's leading researchers and trade groups are urging the need for a common descriptive language to improve how the quality and value of hard cider products is communicated. In this dissertation, I explore the use of qualitative research methods, traditional methods of sensory analysis, and novel text mining approaches to explore sweetness and dryness scales commonly used on cider products, consumer and producer perceptions of cider quality, cider sensory characteristics, and cider product marketing on websites – all within a sample of the Northeast and Mid-Atlantic US cider industry and marketplace.

## *Literature Review*

### Cider History and Background

Apples and cider are iconically American. In the US, apple growing began with North American indigenous communities who grew crabapples (Abrams & Nowacki, 2008; Calhoun, Jr., 2010; Kerrigan, 2008), followed by early European settlers who began organized orcharding. With the dawn of the American Revolution and colonial independence, landowners including the inaugural president George Washington, required their tenants to plant apple trees and it is estimated that by the 1800's almost every home in colonial New England sustained an apple orchard (Futrell, 2017; A. F. Smith, 2014). Historically, apples were used for a variety of purposes: fresh-eating, cooking, preservation, and for converting into other value-added necessities (Thornton, 2002). Apples, unlike many other domestically available fruits, could be stored for a long period of time after harvest and were well-suited for the growing climate of the continental US (Watson, 2013).

From apples, the making of cider was a fixture for many. Historically, apples were brought to a community-shared mill and pressed into juice before being fermented into cider in barrels. Hard cider, as it is also called in the US, is by traditional definition the alcoholic beverage made from fermenting apple juice, and typically contains about 5-8% alcohol by volume (Proulx & Nichols, 1980). Culturally, cider was viewed as both the "poor man's drink" and the US Founding Fathers' beverage of choice, being a daily beverage of choice for many Americans (Proulx & Nichols, 1980; Watson, 2013). Even during colonial times, different apples from different regions were known to yield ciders of different quality and flavor (A. F. Smith, 2014). However, the omnipresence of cider-drinking turned bleak with the dawn of the late 19th century which ushered in the arrival of pest diseases, an influx of German immigrants, and temperance activists (Watson, 2013). Prohibition, which was advertised with emblems of axes (i.e., for the cutting down of apple trees) and slogans identifying the orchard as "the devil's orchard" (*The Devils Orchard*, 1890), was a fatal hit to the home orchards, cider production, and cider-drinking habits of many early Americans, particularly those in the Northeast and Mid-Atlantic early American colonies (Aaron & Musto, 1981; Guttmann, 2012; Jordan, 2016; Kerrigan, 2008; Rorabaugh, 1991; A. F. Smith, 2014; M. Smith & Lal, 2017; Thornton, 2002).

Within this history, the exploitation of slave labor was also critical for sustaining colonial plantation orchards and growing cider culture. Thomas Jefferson, an avid cider consumer and trades-man, was reported to work closely with his slaves Jupiter Evans and George and Ursula Granger, who led most apple-growing and cider-bottling efforts on Jefferson's estate, Monticello (Hayes, 2021; Stanton, 2012). While many of the truths about the role of slavery in growing apples and making cider are undocumented, they receive ample attention in the popular press (Brennan, 2019; Hayes, 2021; Maki, 2019; Pucci & Cavallo, 2021; Richard, 2022). Relatedly, other scholars have discussed how whiteness is pervasive in the craft brewing and hops industries (Carney, 2022), how federal funding for agricultural lands are well-documented to stem from inequities related to skin color (Horst & Marion, 2019; Quisumbing King et al., 2018), and how the present apple farming industry relies heavily upon immigrant labor (Weiler, 2021). All of this to say that the growing cider industry is host to divisive yet relevant pressures stemming from racial disparities within agriculture.

In spite of the preceding challenges, American hard cider is experiencing a renaissance in the present alcoholic beverage industry (Fabien-Ouellet & Conner, 2018; Jacobsen, 2020, 2021, 2022; Kline & Cole, 2017; Lombardo, 2020). A leading apple-growing and cider-making region is the Northeast and Mid-Atlantic US, where New York, Virginia, and Vermont are ranked 1st, 8th, 12th respectively as states with the most cideries (West, 2018). The Lake Champlain Watershed, Hudson Valley, Finger Lakes, and Shenandoah Valley regions in particular have supported active orchards and cider-making cultures for centuries (Watson, 2013) and are home to economies that thrive off of seasonal tourism related to apple-picking and cider-drinking (Kline & Cole, 2017; M. Smith & Lal, 2017). As well, the cider industry is supported by a growing number of regional and local brands which support local and oftentimes rural economies (Brager, 2019), as well as commercially operating orchards (Miles et al., 2020; Ostrom et al., 2022). The North American cider industry is also well-supported by the research efforts of multiple land-grant universities, which have contributed significant research to understanding the barriers, challenges, and economic potential of the cider industry (Becot et al., 2016; Fabien-Ouellet & Conner, 2018; Miles et al., 2020; Ostrom et al., 2022; Peck &

Knickerbocker, 2018). As well, the US and North American cider industry is supported by two leading business trade organizations: the American Cider Association (ACA) and the Cider Institute of North America (CINA).

## Making Cider

Cider can be made according to varying methods, produced over varying amounts of time (which can range from a few weeks to many months), and from many different types (i.e., cultivars or varieties) of apples – all of which can have an impact on cider quality. Traditional cider-making involves the pressing of fresh apples into a juice, and the fermentation of the resulting juice using either natural (i.e., endogenous) or domesticated (i.e., commercial) microorganisms. However, cider can also be made from reconstituted apple juice concentrate or from apple pomace that is steeped with water, the latter of which is a French wine-making technique that results in a beverage traditionally called *piquette* (Robinson, 2015). For the past few decades, Proulx and Nichols (1980) and Lea (2008) have served as guideposts for the step-by-step production of cider. Regardless of the explicit production techniques used, cider in the US is classified as "hard cider" by law if apple juice or reconstituted juice from concentrate represents more than 50% of the final volume of the product (27 CFR § 24.332 - Hard Cider Materials, n.d.).

To date, significant research has been conducted in the cider industry to highlight the effects of production factors on fermentation kinetics and cider quality. Most critically, apple juice is known to have extremely low yeast assimilable nitrogen (YAN) content, which can impact the sensory quality of a resulting cider (Boudreau, Peck, Ma, et al., 2017; Boudreau, Peck, O'Keefe, et al., 2017; Karl et al., 2020). As well, polyphenols in the skins of apples can contribute bitterness and astringency to a finished cider (Lea & Arnold, 1978; Ma et al., 2019; Thompson-Witrick et al., 2014). Other factors of cider production that have been explored in the scientific community include but are not limited to the effects of apple harvest techniques (Alexander et al., 2018), the effects of amino acid composition on cider fermentations (Ma et al., 2018), the effects of nutrient additions on cider fermentation (Rosend et al., 2020), and the effects of wild fermentation methods on final cider quality (Littleson et al., 2022). While the details of most cider production methods and analytical research is beyond the scope of this dissertation, many of these works are useful for framing the growing expertise on cider, particularly pertaining to cider sensory quality.

Apples are the agricultural commodity at the core of cider. Historically, the continental US was home to thousands of apple varieties ranging from sweet and edible right-off-the-tree to small, bitter, and excessively astringent. Dessert or table apples are those used for fresh eating or cooking and are commonly available at the grocery store. Culinary apples are those which harbor more cellulose and are thus particularly useful for cooking, where they retain their shape while simultaneously providing sweetness and acidity for flavor (Calhoun, Jr., 2010). Cider-specific apples are those specifically grown and intended for cider production, and these apples generally offer more polyphenols, including tannins, in addition to some varieties offering higher levels of sugar and acidity. Cider-specific apples generally fall into one of four categories: sweet, bittersweet, sharp, and bittersharp. Crab apples are another sub-category of cider-specific varieties that are traditionally less than 2 inches in diameter (Proulx & Nichols, 1980) and offer extremely high levels of polyphenols (Proulx & Nichols, 1980; Thompson-Witrick et al., 2014).

Though the US has been home to this wide variety of apple types, commercialization and industrialization of the US food supply changed dramatically following Prohibition and post-World-War-II efforts (Guptill et al., 2017; Trubek, 2008), which spawned most domestic apple orchards to "get big" by growing limited numbers of select apple varieties in bulk (Futrell, 2017; Watson, 2013). These sentiments are most clearly exemplified by Virginia Tech Cooperative Extension materials from the 1950's that urged apple growers to grow one of six varieties to either sell on the fresh market or to sell via wholesale to applesauce and non-alcoholic juice purveyors (Marini, 1998). Today, the US apple-growing industry is home to a majority of large, commercial apple-growing operations that continue to sell mostly dessert or table fruit to the fresh market (Tepe & Hoover, 2018). In the context of cider-making, apples that are not pretty enough to sell on the fresh market (i.e., cull apples) can be sold for a lower premium to cider-makers and turned into cider – a sustainable way of repurposing fruit that would otherwise go to waste.

Because so many factors contribute to the final quality of a cider product, industry stakeholders, researchers, and producers have developed cider style guidelines that differentiate cider into broad categories based on the apples that are used, flavor, and the use of non-apple ingredients (Alexander & Ewing Valliere, 2020; United States Association of Cider Makers, 2018). Currently, the style distinctions in the cider industry include standard ciders (e.g., modern and traditional ciders), specialty ciders (e.g., hopped, mixed fruit, spiced, wood-aged, unlimited ciders), and distilled and intensified ciders (e.g., ice and fortified ciders), according to the ACA and Alexander & Ewing Valliere (2020). Of these styles, the two designations that are used most often are "modern" and "traditional" cider classifications. Modern ciders are identified as those produced from culinary or dessert apples and they tend to be lower in tannin, higher in acidity, and light and refreshing sensorially. Traditional ciders are identified as those produced from primarily multi-use, cider-specific, and/or wild or crab apples, and they tend to have higher levels of tannins and sensory complexity (Alexander & Ewing Valliere, 2020). Traditional ciders can also include ciders that are comparable to those made in other countries, such as Basque-style cider (Spain) or Normandy-style cider (France).

In describing traditional ciders, cider industry stakeholders and producers have also used the terms "harvest-driven," "orchard-based," and "heritage" (W. Smith, 2022; United States Association of Cider Makers, 2018), though these terms are largely based on cider-making approaches and techniques that have unknown effects on sensory quality. As well, traditional ciders have also been called "heritage" ciders, though that distinction recently changed to "traditional" or "heirloom" to be more culturally inclusive (Maki, 2019; United States Association of Cider Makers, 2018). Lastly, cider products can be classified according to how many types of apples are contained in the beverage: ciders made using only one apple variety are often called a "varietal" or "single varietal cider," and those made with multiple apple varieties are called a "blend" or "blended" cider (Alexander & Ewing Valliere, 2020; Dawson et al., 2019).

In spite of this growing body of knowledge about cider, actors in the cider community have expressed challenges regarding cider marketing, language, and identity, describing how "the nascent industry currently lacks universal guidelines and even a definition of what cider actually is" (Demmon, 2019). As an example, the cider industry has a reputation of discontinuity related to the sweetness and dryness of cider products (Kessinger et al., 2020; McGrath, 2018; Phetxumphou et al., 2020). Thus, industry stakeholders have urged the need for more clear and

consistent communication regarding cider quality. While various researchers have taken to exploring consumers' sensory preferences (Cole et al., 2022; Kessinger et al., 2020; Tozer et al., 2015) and valuation (Farris et al., 2019; Jensen et al., 2021; M. Smith et al., 2021; Tozer et al., 2015; Yenerall et al., 2022) for cider in order to gain a better grasp of factors which drive consumer interest, the question of how these such factors should most effectively be communicated still remains.

## Sensory Science

Cider is inherently a beverage intended for consumption. Accordingly, sensory science is a field that aims to evoke, measure, analyze, and interpret responses before, during, and after consumption as perceived through the senses of sight, smell, touch, taste, and hearing (H. T. Lawless & Heymann, 2010c). Over the past century, standardized principles and practices have been developed and confirmed to provide structure and control for conducting sensory science testing. The sensory field works to use humans as analytical instruments, often assuming that a large sample of consumers should have enough diversity in their sensory perceiving abilities and sensory preferences to represent themes that apply to the broader population. Sensory science also uses humans as analytical instruments that can be trained to perceive certain attributes or qualities in a consistent, reliable fashion in order to discern concrete sensory differences amongst a selection of products. Overall, the sensory field aims to broadly make the subjective sensations involved in tasting objective and quantifiable.

In the sensory field, a variety of statistical and experimental methodologies can be used to explore specific sensory-related issues including affective responses, whether there is a perceptible difference between products, and descriptive analyses. In the former, most traditional affective testing (i.e., hedonic testing) has involved the choosing of one sample over another or the use of line scales, which ask consumers to rank their liking of a product on a numerical scale (Jones et al., 1955). While these methods are effective in quantitatively and quickly measuring collective trends in product liking, they can be limited in their approach due to the subjective nature and high variability of the human sensory experience. In addition, the sensory experience as a whole is highly contextual (Betancur et al., 2020; Kim et al., 2016; Lahne et al., 2014; Meiselman, 2019; Nijman et al., 2019), meaning that the liking of and sensory perception of products is not solely based on intrinsic qualities alone. Context refers to *any* factor which influences the judgment of a product, including but certainly not limited to environmental conditions, the ordering of samples, product information, and more (H. T. Lawless & Heymann, 2010a; Meiselman, 2019).

In the case of descriptive sensory research, descriptive analyses aim to quantify the perceived intensities of explicit, individual attributes in a food product while neglecting elements of acceptance or liking (H. T. Lawless & Heymann, 2010c). Classical or generic descriptive analysis utilizes a trained panel of tasters, as opposed to regular consumers, in order to consistently gauge tangible sensory qualities within a select group of products. More detail on these sensory methods will be provided in future sections though briefly describing them here serves to highlight the various forms of sensory testing, all of which can have meaningful repercussions for food industry stakeholders and developers by exposing aspects of consumer liking and product quality.

## Cider Sensory Quality

As with many other foods and beverages, tastes, aromas, and mouthfeels are key components of the cider-drinking experience. Cider aromas can vary significantly and impact the perception of sweetness (Symoneaux et al., 2015). Cider polyphenols, also known as tannins, can impact the perception of sweetness, sourness, bitterness, and astringency (Lea & Arnold, 1978; Symoneaux et al., 2014, 2015). Some researchers have precluded the importance of overall sensory flavor in consumer preferences for cider, as opposed to individual attributes (Tozer et al., 2015), while others have looked at consumer preferences for specific sensory qualities. Sensory affective testing with cider has revealed that consumers generally like berry-like, fruity, crisp, and fresh apple flavors, but that consumers dislike putrid, woody, earthy, and musty flavors (Phetxumphou et al., 2020). Cole et al. (2022) recently observed clusters of consumers who each preferred different sensory qualities; for example, one cluster preferred sweet ciders that lacked off-flavors, another cluster favored sweet ciders with off-flavors, and still another cluster disliked sweetness and off-flavors. Consumers have also been observed to discriminate ciders according to tartness, dryness/bitterness, and fruity/sweetness (Kessinger et al., 2020) as well as citrus, floral, tropical, and baked/fresh apple notes (Qin et al., 2018).

As briefly mentioned, much debate has existed regarding cider dryness and sweetness (Alexander & Ewing Valliere, 2020; Kessinger et al., 2020, 2020; McGrath, 2018), which have been traditionally discussed as opposing sensory features wherein dryness is the complete absence of sugar and sweetness. However, multiple sensory studies have shown evidence of consumers using the both of the terms ‘dry’ and ‘sweet’ to describe the same cider products (Kessinger et al., 2020; Phetxumphou et al., 2020). In 2018, the New York Cider Association developed the Merlyn Dryness Scale to describe the sensory dryness and sweetness of cider products based on chemical attributes (New York Cider Association, 2019; New York Cider Association (NYCA), 2019). This scale, based on the dryness-sweetness scale developed by the International Riesling Foundation (International Riesling Foundation, n.d.) to describe Riesling wines, uses measures of titratable acidity, residual sugar, and polyphenol content to calculate a cider’s dryness-sweetness as either “dry,” “semi-dry,” “semi-sweet,” or “sweet.” However, the efficacy of the Merlyn Dryness Scale for accurately predicting the sensory dryness-sweetness of American cider products has not been demonstrated and is an ongoing need for the industry.

## Descriptive Analysis

Within the category of sensory descriptive testing, sensory Descriptive Analysis (DA) is the gold standard methodology (Heymann et al., 2014; H. T. Lawless & Heymann, 2010b). This research method involves training a panel of tasters to identify and evaluate the intensity of all of the sensory attributes of a product (Heymann et al., 2014; H. T. Lawless & Heymann, 2010b). Sensory attributes can describe any sensory modality including taste, smell, texture, mouthfeel, and appearance. The training of panelists is usually accomplished in one of two methods: (1) consensus training or (2) ballot training. A traditional consensus-trained DA involves panelists being trained by a moderator to identify, agree upon, and characterize attributes within multiple products. In a DA panel, panelists try a variety of products within a given product category and

brainstorm every attribute that they can identify related to each of the aforementioned sensory modalities. Then, attributes are narrowed down to combine similar terms, and attributes are defined in reference to a separate food product or concoction, called a reference standard. After all of the attributes and references of products are established, the panel again assesses various products within a product category and rates each attribute that they previously defined for all product samples. Descriptive analysis usually requires a long-term time commitment of 8-12 panelists. Data from DA panels is evaluated using multivariate and univariate statistics to measure the significance of individual attributes in separating and describing the product space (Heymann et al., 2014).

Descriptive analysis has been used successfully to develop a thorough list of sensory attributes for various foods (Batziakas et al., 2019; Chambers et al., 2016; Delgado & Guinard, 2011; Hough & Sánchez, 1998; Young et al., 2005), as well as alcoholic beverages (Heymann & Ebeler, 2016; Lahne et al., 2019; Meilgaard et al., 1979; Noble et al., 1987) and American hard cider (Cole et al., 2022; Littleson et al., 2022). Comprehensive lists of a product's sensory attributes are then used to build sensory lexicons (Drake & Civille, 2003; L. J. R. Lawless et al., 2012), which are graphical representations of sensory attributes usually in a visually-appealing, circular wheel format. Oftentimes, multiple lexicons are made to separate the sensory modalities, such as having one lexicon for flavors and one lexicon for aromas, as is the case for the well-known coffee flavor wheel by Counter Culture Coffee. Lexicons have been made to characterize a large variety of food products (Chambers et al., 2016; Chun et al., 2020; Civille et al., 2010; L. J. R. Lawless et al., 2012; Noble et al., 1984, 1987) and have been shown to be useful in helping consumers identify product attributes (Phetxumphou et al., 2017). However, while some recent studies have utilized DA methods to explore the sensory space of American cider products (Cole et al., 2022; Littleson et al., 2022), these works have not included a large sample set of products that is representative of the whole product category cider currently available in the marketplace. Therefore, a sensory DA conducted with a large, representative sample of cider products is critical for understanding the sensory attributes that constitute specifically American cider products and for ultimately building a sensory lexicon to improve cider communication.

### Qualitative Research

As previously mentioned in brief, traditional affective testing can be limited in its ability to measure *what* individual elements are liked in the product experience and *why* certain attributes or qualities are liked over others. At the same time, the sensory experience is much broader than the moment of consumption (Aquilani et al., 2015; Gómez-Corona et al., 2016, 2017; Lahne et al., 2014; Lahne & Trubek, 2014), and so perceptions and preferences of foods and beverages can be heavily influenced by context (Betancur et al., 2020; Calvo-Porral & Levy-Mangin, 2019; Lahne & Trubek, 2014). Accordingly, scholars in the sensory science community have urged sensory research to move into more contextual settings so as to acknowledge and explore the environmental factors which influence consumers' sensory experiences, and to increase the real-world validity of sensory and consumer research (Meiselman, 2013, 2019; Meiselman et al., 2022).

Where traditional, quantitative sensory research helps to identify the measurable sensory and chemical characteristics of food and beverage products, qualitative research allows

consumers to discuss their needs, wants, motivations, and habits without a predefined structure, openly and freely. Specifically, phenomenology is a type of qualitative research that helps give meaning to a phenomenon, experience, or circumstance in the terms, context, and moments in which it is experienced by one person or a group of people (Creswell & Poth, 2018). In the context of food and beverage research, phenomenologies can be useful for broadly identifying how a food or beverage is enjoyed, described, consumed, or produced. Accordingly, these methods are becoming increasingly popular for studying consumer preferences, purchasing habits, and consumption patterns (Barlagne et al., 2017; Cardinal et al., 2003; Chung et al., 2011; Gómez-Corona et al., 2016, 2017; Lahne & Trubek, 2014; H. T. Lawless & Heymann, 2010d; Silva et al., 2016). As a whole, qualitative research methods have been foundational in the fields of sociology and anthropology for exploring values-systems within food and beverage production by helping to paint a rich, thick description of all that goes into crafting a food or beverage.

The pillars of qualitative research are philosophical assumptions, an approach, inductive and deductive analysis, and a complex description of the experience (Creswell & Poth, 2018). Philosophical assumptions address the nature of knowledge, or how researchers determine what counts as "findings" and "results," and what these established findings mean in regard to the broader population. The *critical realist* ontology is a perspective common for qualitative research which asserts that a knowable and observable world is only partially accessible by the researcher – the researcher cannot truly know what their subjects experience because they themselves are only subjectively observing the experiences of others (Braun & Clarke, 2013; Tebes, 2005). The *contextualist* epistemology asserts that observations made by researchers are unique to the context in which the research took place, and so subsequent observations and results are only one "truth" among many other "truths" that may have been observed if the research was conducted in a slightly different environment, with slightly different participants and researchers (Braun & Clarke, 2013, p. 31). These philosophical assumptions underpin the qualitative research presented in this dissertation.

Focus groups and interviews are common approaches to conducting phenomenological research. Focus groups are discussions among a small group of people with shared characteristics or experiences, and interviews are one-on-one discussions between a participant and observer. Both methods of qualitative research involve genuine discussion about participants' beliefs, attitudes, and motivations in a format that is focused yet flexible, often guided by a moderator and semi-structured questioning route (Krueger & Casey, 2015). These questioning routes can range from a concise, brief overview (with a few sample questions; Lahne & Trubek, 2014) to very detailed (noting every question that was planned; Cardinal et al., 2003). Focus group research methods in sensory science can also involve the provision of food product samples to stimulate discussion and to guide participants in "revealing their opinions" (Charters & Pettigrew, 2007; Crump et al., 2014; van Kleef et al., 2005). Most importantly, focus groups and interview sessions are traditionally audio-recorded and transcribed, and the resulting transcriptions form the "data" which are analyzed for dominant, reoccuring themes and important quotes (Braun & Clarke, 2013; Creswell & Poth, 2018; Krueger & Casey, 2015).

Within qualitative research on food and beverage products, one of the most traditional, well-observed methods of data analysis of qualitative data has been the use of reflexive thematic analysis. Reflexive thematic analysis is a revised form of thematic analysis originally

developed by Gerald Holton in the 1970's (Holton, 1973) and further refined in recent years to include more insight and reflection on behalf of the researchers (Braun & Clarke, 2006, 2013, 2019; Clarke & Braun, 2014). Reflexive thematic analysis is a process of exploring quotes with consistent themes or topics and categorizing those topics into broader themes that can be contextualized based on the environment in which the research took place as well as in regard to other research. In addition, the researchers should reflect upon how their background and biases can influence their analyses of quotes and topics collected from the research.

Regardless of the methodological tools used, qualitative research has been critical for investigating the preferences for a large variety of products from peanut butter to yams to wine (Barlagne et al., 2017; Charters & Pettigrew, 2007; Crump et al., 2014; Lahne & Trubek, 2014; McNeill et al., 2000). Specifically with wine, qualitative research has indicated that consumer preferences can be largely influenced by their expertise, product knowledge, occasion for consumption, and even third party opinions or expert ratings (Bruwer et al., 2011; Charters, 2005; Charters & Pettigrew, 2007). With artisan cheese and craft beer, qualitative research has shown that the story behind how a product was made and the social context in which it is consumed can influence both consumers' preference and their actual perception of a product (Gómez-Corona et al., 2016, 2017; Lahne et al., 2014; Lahne & Trubek, 2014).

It is important to note that most qualitative research methods utilized in the sensory science space have aimed to explore the preferences of consumers. Producers on the other hand are a special breed of consumers that are often assumed to be extremely educated and self-aware of the product industry in which they engage. However, producers can also be new to their product industry, transferring the morals and ideals of their other careers and lifestyle into a new industry. In such, different producers may have conditioned or evolving definitions of quality in terms of what they make, how they make, what they taste, and how they taste. To date, sensory research has exposed the ways in which experts and professionals, including *producers*, discuss and prefer foods and beverages differently compared to "normal" consumers (Ballester et al., 2008; Hopfer & Heymann, 2014; Langlois et al., 2011; Parr et al., 2002, 2004; Schiefer & Fischer, 2008; Souza Gonzaga et al., 2020; Wang & Spence, 2019). For example, Ballester (2008) showed evidence of experts having higher discernibility in wine typicality. In addition, Langlois et al. (2011) and Giacalone et al., (2016) discussed how wine and beer professionals use language that is more technical and descriptive as opposed to emphasizing their subjectivities. These works seem to suggest that producers offer a unique approach to discerning and discriminating quality as an effect of their product expertise, though researchers have minimally explored producers' *values* regarding taste and consumption given their acute sensory abilities.

## Sociological Frameworks

Traditional food science research which takes on quantitative forms of data analysis does not traditionally consider how scholarly theories in the fields of sociology, anthropology, or economics influence actors and commodities in the food and beverage industries. However, because this dissertation utilizes qualitative research methods as a backbone for exploring consumer and producer perceptions, various works in the pre-described fields have been fundamental in framing the research questions and results.

In building off of previous discussion, most sensory and economics research in the food sector has explored consumer preferences for products because these findings are critical for motivating producers to make new and satisfying products (van Kleef et al., 2005). In contrast, most sociological and anthropological research has investigated how and why producers make and share food or beverages products (Warde, 2016). This simplistic overview of dichotomous research goals has been described as a "production-consumption debate" wherein producers and consumers are viewed as two distinct, separate entities which compete for the power to influence each other; contributing to a dueling, non-empathetic food system (Goodman & DuPuis, 2002; Warde, 2016). In other words, researchers have traditionally either studied "how we grow food" or "how we know food" (Goodman & DuPuis, 2002, p. 6), but have often neglected combining the two. It is in this regard that I attest, with the research presented in this dissertation, the use of sensory-oriented producer-based qualitative research as one tool complimentary to consumer focus groups that exposes how producers have the unique ability to emplace their own preferences and values onto the products that they make and push into the food supply, subsequently influencing consumers. Instead of looking at producers through the lens of what they make and how they make, this research asks producers how "what they make" and "why they make" compares to what they consume and why they consume. While there is no established method for abridging the production-consumption debate (Warde, 2016, p. 14), this dissertation can be viewed as one approach to investigating producers and consumers and the effects they have on each other.

The concept of *terroir* has also been highly influential on the present research. *Terroir*, as elaborated upon by countless scholars, is an all-encompassing category of discerning food and beverages that links taste, place, and agriculture and that originated in French culture. Amy Trubek (2008) describes *terroir* as a foodview that frames peoples' relationships with land and the agricultural products therein (p. 18). The underlying notion of *terroir* is that foods or beverages made in a certain place should express sensory qualities that are the result of the natural elements of the product's place of origin. In this way, environmental elements such as soil type, climate, and air quality all strongly affect the essence of *terroir* in a food or beverage product. At the same time, *terroir* also encompasses human and cultural elements wherein consumers must find value in products because of their geographic origin. Producers must also minimally manipulate or adjust a raw material to ensure that its integrity, drawn from a collective of environmental factors, purely translates into the finished product's sensory quality. *Terroir* has been discussed most extensively in wine (Daynes, 2013; Kustos et al., 2020; Trubek, 2008; Zheng, 2019), artisan cheese (Paxson, 2010), and hops (Van Holle et al., 2021). Concurrently, various cider producers make ciders using the same apple varieties but grown in different regions (Brennan, 2019; Pucci & Cavallo, 2021) to explore *terroir* in American cider, and even apple growers have documented ways in which cultivars can vary when they are grown in different parts of the United States (Calhoun, Jr., 2010).

Qualitative research in the artisan cheese industry has inspired much of the discussion presented in this dissertation. In her 2013 ethnography of artisan cheesemakers, Heather Paxson detailed the economic and ethical facets of the artisan cheese movement. Her research offers relevant insights regarding the reordering of consumer and producer values, critically discussing how producers are evolving to care about their agricultural land and resources in a way that motivates them to use land harmoniously and ethically – what Paxson refers to as the

*post-pastoral.* Paxson also details various economic forces on artisan and agricultural food production as well as emotional forces that influence why producers become artisan cheesemakers to begin with. She offers critical insights as to how cheesemakers use story-telling and community education to add value to their products. The works of Heather Paxson have more recently motivated qualitative investigations into the consumer sensory experience, demonstrating how production information and social context are among other factors highly influential on the sensory experience of Vermont artisan cheese (Lahne & Trubek, 2014).

Other works that have been instrumental in the ideas presented in this dissertation include those of Hennion (2007) and Hennion and Teil (2018) – who detail the process of active and reflexive tasting as a sociological phenomenon. These authors describe how some consumers have a close affinity for certain products and pay close attention to the nuances of the tasting experience, thus referring to them as *amateurs*. Overtime, the *amateur* becomes trained to perceive certain tastes and becomes influenced by and ingrained into cultural communities who engage in tasting in the same ways that they do. Hennion and Teil (2018) specifically offer insight into the spectrum of *amateurship*, describing how different levels of expertise are possible. These authors also show evidence of taste being highly influenced by environmental context including the consumption occasion and product information, both of which can influence reflexive tasting behaviors. Because much of this dissertation looks at holistic and contextual tasting experiences, these works have inspired reflection about how producers and consumers participate in active and reflexive taste experiences depending on their level of *amateurship*.

Of note, other works that have been useful for contextualizing findings presented in this dissertation include Labelle's discussions about increasing knowledge and connectedness in food systems (Labelle, 2004), various scholars' ideas about social loyalty in economic systems (M. Granovetter, 2011; M. S. Granovetter, 1973; Hinrichs, 2000; Polanyi et al., 1957), economic tension (Gudeman, 2008), David Sutton's sentiments about nostalgia in food cultures (Sutton, 2001, 2014), and discussions of food and identity (Guptill et al., 2017). These ideas serve as a framework for understanding consumer and producer values for American cider in the proceeding sections.

## Language and Communication

Within the fields of food science and sensory research, in addition to other fields such as anthropology and linguistics, the study of food-related language has become a focus in recent years. Food-related language offers invaluable insights for understanding how producers, consumers, and other actors communicate the *quality* of food, alongside a host of other actions that involve language within the food and beverage space (i.e., recipe preparation). Qualitative research, such as content and document analyses and thematic analysis, have been used to explore overarching themes and sentiments across food-related text. However, the rise of the internet has given way to vast quantities of language about food and beverage that are far too exhaustive to explore manually through traditional qualitative techniques.

Natural Language Processing (NLP) is a toolbox of quantitative, computerized text analysis methods that can be used to quickly and efficiently explore how humans communicate through language. Within NLP, text mining involves extracting unstructured and structured text and applying statistical techniques to predict and discover patterns across text. Recently

developed, topic modeling is a category of text mining that aims to explore broad topics within a dataset much in the same way as thematic analysis is used to identify themes in qualitative research. Topic modeling methods such as Latent Dirichlet Allocation (LDA) and Biterm Topic Modeling (BTM) use a mathematical model to investigate word co-occurrence patterns across both large and small units of text, such as books and tweets, respectively (Cheng et al., 2014; Jurafsky & Martin, 2021; Yan et al., 2013). Because the internet has become a host for discussing food and beverages in both short (e.g., product descriptions) and long (e.g., product reviews) forms of text, many researchers have taken to using text mining and topic modeling techniques to explore food and beverage discussions on Twitter (Feldmeyer & Johnson, 2022; Puerta et al., 2020; Vidal et al., 2015), subreddits, online review platforms, blogs, and more (Danner & Menapace, 2020; Hamilton & Lahne, 2020). Increasingly popular, text mining can be valuable for improving our understanding of language and communication in the food and beverage space, especially relative to the product sensory experience.

## *Objectives and Overview*

With this foundation of popular and scholarly knowledge, this dissertation utilizes a mixed-methods approach to generate a rich, detailed understanding of the cider sensory experience as it is experienced by a multitude of people and a multitude of senses before, during, and after consumption. In this dissertation, I pilot common qualitative research methods for their application in the sensory field, and I potentiate the pros and cons of such research methods in sensory science research. With related findings, I discuss prevailing trends in local and regional food systems, the alcoholic beverage industry, and artisan food systems in the context of sociological and economic theories. This dissertation also includes a thorough account of the use of traditional sensory methods to quantitatively distinguish a large representative sample of cider products made in the Northeast and Mid-Atlantic US. Lastly, I employ emergent text mining approaches to explore the language that is used in cider product marketing on cidery websites, reflecting upon how this information may impact product sensory experiences and perceptions. All of the present research was conducted in or with products made and sold in Virginia, Vermont, and New York to serve as a snapshot of the Northeast and Mid-Atlantic US cider industry.

First, I investigate the efficacy of the Merlyn Dryness Scale in predicting consumers' sweetness and dryness perception in three cider products. The use of a visual scale which communicates dryness and sweetness in American cider products is prevalent. In 2018, the New York Cider Association developed a scaling method that uses chemical parameters (i.e., titratable acidity, residual sugar, polyphenol content) to determine the sensory dryness and sweetness of cider products. Chapter 2 discusses a chemistry and sensory study in which we piloted the Merlyn Dryness Scale on three commercial cider products served at different temperatures, in order to test the validity of the scaling method based on cider chemistry and to explore the effects of serving temperature on dryness and sweetness perception in hard cider.

Second, I utilize sensory Descriptive Analysis (DA) to characterize the sensory attributes of a large, representative sample of cider products from Virginia, Vermont, and New York. Sensory DA is the standard methodology (Heymann et al., 2014) for characterizing the sensory dimensions of a product category. This study involved an eight-person panel that was trained for

a total of 13 hours following the consensus training method, afterwhich 33 total attributes were found to describe a sample of 42 cider products. With this research, I present a broad set of descriptive terms which significantly discriminate cider products (N=29), as well as preliminary evidence into factors which may explain and predict the nature of sensory differences across American cider products. I also discuss how this research is critical for improving sensory communication in the cidery industry and how this research can be leveraged to develop future projects.

Third, I demonstrate the use of phenomenological, qualitative research methods in the form of focus groups, to explore consumer preferences of cider and the cider-drinking experience. Chapter 4 discusses methods of reflexive thematic analysis (Braun & Clarke, 2006, 2013, 2019) followed by a rich, detailed discussion of themes which heavily influence consumer preference for cider. I contextualize findings of this qualitative research with reference to concepts such as active and reflexive tasting (Hennion, 2007; Teil & Hennion, 2018), *sentir le terroir* (Trubek, 2008), the artisan cheese movement (Lahne & Trubek, 2014; Paxson, 2010, 2013), and social embeddedness (M. Granovetter, 2011; M. S. Granovetter, 1973; Hinrichs, 2000; Polanyi et al., 1957; Portes & Sensenbrenner, 1993) to highlight consumers' appreciation for local products and nostalgia related to their cider-drinking communities.

In Chapter 5, I continue the use of phenomenological research, but employ personal interviews to explore cider producer preferences of cider and their cider-drinking experiences. Studying cider producer perceptions serves to bridge the divide in consumption and production studies (Goodman, 2002; Goodman & DuPuis, 2002; Warde, 2016), as well as to elucidate the ways in which producers impact product industries beyond simply making products to begin with. In this chapter, I highlight themes of producer preference and contextualize these themes with reference to active and reflexive tasting (Hennion, 2007; Teil & Hennion, 2018), Marxist theory, Heather Paxson's conceptualization of *unfinished commodities* (2013), and Stephen Gudeman's ideas on economic tension (Gudeman, 2008).

In Chapter 6, I pilot the use of the so-called "tidy-text" mining approach and BTM to explore how cider producers and marketers describe cider products on cidery websites. NLP tools such as topic modeling have been recently developed to explore topics and patterns in relatively small text-based datasets (Cheng et al., 2014; Wijffels et al., 2021; Yan et al., 2013). To be specific, BTM has been previously used to explore consumer perceptions of vertical farming and turmeric from consumer reviews and Twitter, respectively (Feldmeyer & Johnson, 2022; Vidal et al., 2015). In this chapter, I explore the frequency of commonly used terms and apple varieties across cider products from different states and in different packaging. I also discuss overarching topics used to describe cider products on websites and I provide recommendations for improving and better understanding cider communication and marketing.

Chapter 7 provides a summary of all results reported on in previous chapters and discusses recommendations for future research. Altogether, this dissertation utilizes a mixed-methods approach to explore consumer and producer preferences and perceptions of American cider, tangible dimensions of sensory quality for a large sample of American cider products, and the use of text mining for understanding verbal communication in the current American cider industry.

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# Chapter 2 – Can Cider Chemistry Predict Sensory Dryness? Benchmarking the Merlyn Dryness Scale


## *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.



## *Keywords*

Check-all-that-apply; consumer liking; hard cider; Merlyn Dryness Scale; sensory


## *Publication Note*

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## *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 (Alcohol and Tobacco Tax and Trade Bureau, 2017; Jacobsen, 2020, 2021; Lombardo, 2020; Moulton et al., 2010). 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 (Demmon, 2019; Fabien-Ouellet & Conner, 2018). 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 (McGrath, 2019). One approach, which has been successful for Riesling wines, is to provide consumers with relative sweetness and dryness of the product using numeric scales (*Riesling Sugar Guidelines*, n.d.). In cider, dryness and sweetness scales could be useful sensory predictors for consumers who are motivated by taste when making purchase decisions (Tozer et al., 2015)**.**

Recently, the New York Cider Association (NYCA) proposed a dryness-sweetness scale called the Merlyn Dryness Scale (New York Cider Association, 2018, 2019). 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 (New York Cider Association, 2018). 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 (New York Cider Association (NYCA), 2019).

This method is intended to account for the ways in which acidity and bitterness can impact the dryness perception of a beverage (Fontoin et al., 2008; Ishikawa & Noble, 1995; Martin et al., 2002; Symoneaux et al., 2014). However, ethanol content can also impact dryness-sweetness sensations, and which may impact the effectiveness of the Merlyn Dryness Scale (Fontoin et al., 2008; Nolden & Hayes, 2015). Though trained cider professionals piloted the Merlyn Scale at the ACA's annual CiderCon conference in 2018 and 2019 (New York Cider Association, 2019), 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 (Ares et al., 2010; Ares & Varela, 2017; Galiñanes Plaza et al., 2019; Risvik et al., 1997).

To date, there are multiple methods of measuring polyphenol content in wine and cider (Boulet et al., 2016; Cheynier, 2005; Lesschaeve & Noble, 2005; Ma et al., 2019), 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 (Ross et al., 2012), 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.

# *Materials and Methods*

## 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, 50mL 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 (Phetxumphou et al., 2020). 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 (Kessinger et al., 2020; Phetxumphou et al., 2020), 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 (Lee et al., 2013), and because term order has been shown to have minimal influence on consumer response (Ares & Jaeger, 2013). 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.

## 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 (New York Cider Association, 2019). The F-C method was adapted from (Spanos & Wrolstad, 1990), 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.

## 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 (New York Cider Association (NYCA), 2019), 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 importances 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.

## *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 (Riekstina-Dolge et al., 2014; Thompson-Witrick et al., 2014), and polyphenols can contribute a bitter taste or drying sensations which can impact dryness-sweetness perception (Fontoin et al., 2008; Ishikawa & Noble, 1995; Lesschaeve & Noble, 2005; Martin et al., 2002; Symoneaux et al., 2014). Ethanol content can also impact dryness-sweetness perception (Fontoin et al., 2008; Nolden & Hayes, 2015), 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 (Green et al., 2010; Mennella et al., 2015); 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 ($\square = 0.64$, $p < 0.05$), indicating that assessment of dryness is explained in some part by consumers' hedonic response to the cider.

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.

## *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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## *Tables*

**Table 2.1.** 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 2.2.** 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 2.3.** 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 2.4.** 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** | **Room Temperature** | **Overall Average** |
| Eden Peak Bloom | 4.37 | $1.76 \pm 1.00$ | $1.90 \pm 0.94$ | 1.83 |
| Buskey RVA Cider | 5.06 | $1.76 \pm 0.83$ | $1.86 \pm 0.89$ | 1.81 |
| 1911 Est. Original | 4.23 | $2.32 \pm 0.80$ | $2.01 \pm 0.99$ | 2.16 |

## *Figures*

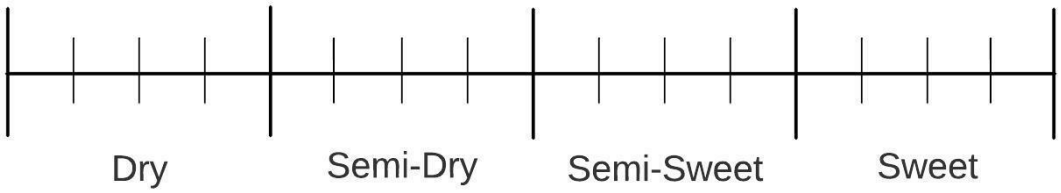


**Figure 2.1.** Merlyn Dryness Scale from NYCA, with quarter-unit increments.

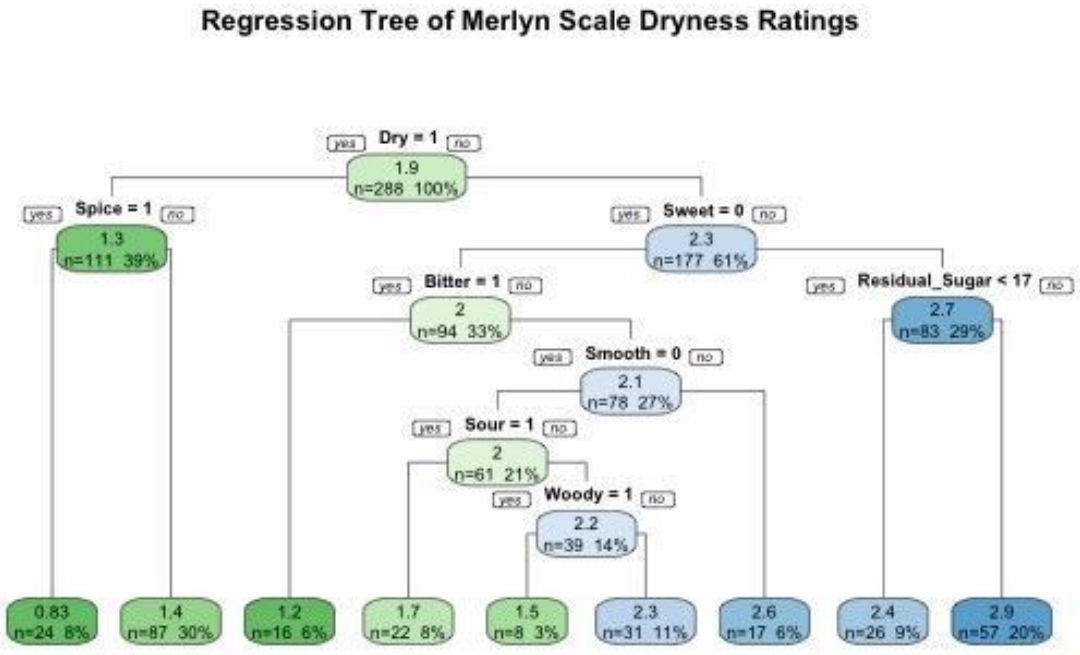


**Figure 2.2.** A Regression Tree for sensory dryness based on CATA attributes, overall liking, and cider chemistry for the Merlyn Dryness Scale. The Regression Tree shows other factors in this evaluation that can be used to predict dryness-sweetness ratings on the Merlyn Scale, while ignoring interaction 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.

# Chapter 3 – Sensory descriptive analysis of hard ciders from the Northeast and Mid-Atlantic United States


## *Abstract*

Although alcoholic or “hard” cider is a beverage of growing popularity throughout the Northeastern and Mid-Atlantic United States, the industry lacks a consistent language for describing the sensory quality of its products. The main objective of this research was to explore the sensory attributes that can be used to describe a large representative sample (N = 42 samples) of ciders from Virginia, Vermont, and New York, using classical Descriptive Analysis (DA). The secondary objective of the research was to determine if a trained panel can significantly distinguish the cider samples based on factors such as style, packaging, and apple varieties. The study was conducted using a standard DA: 8 panelists were trained for 13 hours to develop a lexicon of aroma, taste, and mouthfeel descriptors for 42 cider samples (15 single varietal ciders, 27 blended ciders). Then, subjects evaluated each cider in duplicate for all descriptive attributes in standard sensory-evaluation conditions. Results were analyzed to determine overall differences between the individual cider samples, geographic origins, cider styles, and packaging formats, as well as significant differences across individual attributes. Herein we report on descriptors and intensity rating patterns which significantly discriminate the cider samples, as well as extrinsic product variables. These results provide a framework for describing the sensory characteristics of cider from the Northeast and Mid-Atlantic regions of the United States, which may be further generalizable to other North American ciders. As well, these results explore extrinsic factors which differentiate the sensory characteristics of cider, and which may inspire future research.


## *Publication Note*

This chapter reflects a manuscript that has been submitted for review to the *Journal of Food Science.* The manuscript is currently in its second round of revisions with reviewers. Manuscript authors are Martha D. Calvert, Clinton L. Neill, Amanda C. Stewart, and Jacob Lahne.

## *Introduction*

Alcoholic cider, also known as “hard” cider in the United States (US), is of increasing importance in the alcoholic beverage marketplace. The cider industry in the US has grown substantially in the last 10 years overall, reportedly outpacing the growth of beer, wine, and distilled spirits (Brager 2019; Lombardo 2020; Bloom 2020; Wood 2022).

In efforts to support and encourage the American cider industry’s continued growth, many cider stakeholders, researchers, and producers have advocated for the development of cider style guidelines that emphasize sensory quality (Fabien-Ouellet and Conner 2018). The main style distinction that has gained traction to date is between “modern” and “traditional”

ciders. Modern ciders are identified as those produced from culinary or dessert apples, tending to be generally lower in tannin, higher in acidity, and light and refreshing sensorially. Traditional ciders are identified as those produced from primarily cider-specific apples, tending to have higher levels of tannins and complexity (Alexander and Ewing Valliere 2020). Ciders are also classified by how many types of apples are contained within: ciders made using only one apple variety are termed a “single varietal cider,” and those made with multiple apple varieties are termed a “blend” or “blended” cider (Alexander and Ewing Valliere 2020). Though these style guidelines cover a large spectrum of cider products produced in the US, they do so at the cost of failing to communicate specific sensory qualities (Fabien-Ouellet and Conner 2018; Kessinger et al. 2020).

Broadly, some approaches to categorizing and communicating cider quality also draw on concepts related to *typicity* and *terroir* – related phenomena wherein the sensory characteristics of a product may be related to fruit variety, as well as sociocultural and geographical factors (Ballester et al. 2005, 2008; Trubek 2008; Leriche et al. 2020; Souza Gonzaga et al. 2020). Typicity and terroir in American cider products has been minimally explored, though evidence suggests that geographical origin can contribute to cider chemical and sensory differences in cider products (Le Quéré et al. 2006; Valles et al. 2007; Antón et al. 2014; Villière et al. 2015; Nicolini et al. 2018; Qin et al. 2018; Uthurry et al. 2019). The American cider industry is dominated by prominent apple-growing regions in the northern Midwest, Northwest, Northeast, and Mid-Atlantic US. In the Northeast and Mid-Atlantic, New York, Virginia, and Vermont are the 1st, 8th, 12th ranked states with the most cideries in the US, respectively (West 2018; Conway 2019, 2020).

To this date, researchers have made important contributions to understanding the objective sensory dimensions of US ciders and their origins (Alexander et al. 2018; Bingman et al. 2020; Phetxumphou et al. 2020; Kessinger et al. 2020; Moss et al. 2021; Littleson et al. 2022; Cole et al. 2022). Cider tannins, bitterness, and astringency are well-documented components of the cider sensory experience which can impact the perception of sweetness and sourness (Lea and Arnold 1978; Symoneaux et al. 2014, 2015). Littleson et al. (2022) documented how sensory descriptors can vary significantly across ciders made according to different methods and with different apple varieties. Cole et al. (2022) recently reported on descriptive terms that can be used to characterize ciders from the US state of Virginia. Recent research has also described how consumers use sensory terms to discriminate samples, discern their liking and disliking, and even to judge products based on cider packaging (Phetxumphou et al. 2020; Kessinger et al. 2020; Cairns et al. 2022). In building from previous discussion about how extrinsic product factors (i.e., styles, geography, apple varieties) can be related to sensory quality, research by Kessinger et al. (2020) emphasized how cider packaging is also correlated with different sensory attributes and different consumer perceptions. All of this is to say that apple varieties, geographic origin, cider styles, and product packaging are four primary factors which differentiate cider products and their sensory quality, according to consumers, in the current US cider industry.

The cider industry’s leading trade group, the American Cider Association (ACA), has sought the development of tools to describe and communicate the sensory attributes of cider in order to put consumers and producers on the same wavelength when it comes to “talking cider”(Demmon 2019; McGrath 2019). At the same time, sensory researchers urge the

development of more consumer-relevant sensory models that utilize language that is more approachable and understandable for average consumers (Lawless 1995; Schiefer and Fischer 2008; Varela and Ares 2014; De Pelsmaeker et al. 2019). The use of language that should be understandable for consumers is particularly important for sensory research that aims to develop a sensory lexicon for consumers to use during their tasting experiences (Drake and Civille 2003; Lawless and Civille 2013). Research has also suggested that different consumers may use different descriptors to describe a single cider (Phetxumphou et al. 2020), indicating that the US cider industry is indeed in need of clearer descriptive language developed by trained panels.

Descriptive analysis (DA) is the “gold standard” of descriptive sensory research that utilizes trained panelists to create a meaningful “scientific” language for describing products (Lawless and Heymann 2010; Heymann et al. 2014). DA has been used extensively to describe the sensory properties of a range of alcoholic beverages (Meilgaard et al. 1979; Noble et al. 1987; Donaldson et al. 2012; Heymann and Ebeler 2016; Danner et al. 2018; Lahne et al. 2019; Souza Gonzaga et al. 2020; Senn et al. 2021) and recently has been used to describe limited sets of cider products (Littleson et al. 2022; Cole et al. 2022). Ultimately, the terms generated through DA become the framework for sensory lexicons, visual tools to be used by consumers and industry stakeholders or to be used in further consumer testing (Drake and Civille 2003; Lawless and Civille 2013; Spencer et al. 2016). Therefore, it is critical that DA research utilize descriptive terms that are broadly understandable to consumers yet still specific and descriptive (Lawless and Civille 2013), as well as a large sample set of products that are representative of a whole product category (Lawless and Heymann 2010).

With this background in mind, the objective of this study was to identify sensory attributes that can be used to describe a large representative sample (N = 42 samples) of ciders from key cider producing regions of the USA — Virginia, Vermont, and New York — using classical descriptive analysis (DA). The secondary objective of the research was to determine if these cider samples exhibit sensory differences based on other, possibly extrinsic factors such as product style, packaging, and apple varieties.

# *Methods*

## Sample Selection

For this study, N = 42 representative ciders were selected from commercially available hard ciders produced in Virginia, Vermont, and New York. Ciders were purchased locally from Vintage Cellar (Blacksburg, VA) or ordered online directly from producers. Only ciders made solely with apples were included: no flavored, hopped, or mixed-fruit ciders were included so as to focus on sensory attributes specifically related to apples and the cider-making processes. Products also were required to be made in one of the three states. A mix of single varietal and blended ciders were included in the study as a preliminary investigation into how apple varieties can affect sensory quality.

For sample selection, cider products were randomly chosen (using a random number generator) from a list of all cider products made in Virginia, Vermont, and New York (compiled manually). The primary goal of sample selection was to have approximately equal

representation of ciders produced in the 3 states selected for this study, with secondary consideration given to blended versus single varietal cider, and tertiary consideration given to packaging type. If any randomly selected cider sample was not available to be purchased locally or shipped from the producer, a new sample was selected at random from the list. Single varietal ciders and blended ciders were randomly selected separately because of the difference in the available population of ciders. For blended ciders, ciders randomly selected from repeat producers were eliminated from the study and another cider was selected at random in their place. Because fewer single varietal ciders are made, some single varietal ciders were from the same producer. During sample selection, researchers found that many unflavored and canned ciders from New York were not available outside that state; therefore, most ciders randomly selected and available to be shipped from New York state were in the 750mL glass bottle format. The final samples chosen for the study comprised 12 ciders from Vermont (1 single varietal, 8 traditional), 14 ciders from Virginia (7 single varietal, 10 traditional), and 16 ciders from New York (7 single varietal, 12 traditional), which are described in *Table 1.* All samples were purchased at retail prices and mention of any brand names or manufacturers does not imply financial support or endorsement from associated companies.

## Subjects

Panelists (N = 8: 9 initially with 1 drop out) were recruited from the Virginia Tech and Blacksburg, VA communities. To participate in the study, panelists must have been at least 21 years old, willing to taste hard cider, and available for training and evaluation sessions. Panelists received two gift cards following completion of the training and evaluation phases of the study. An assortment of snack foods and desserts were also provided as further incentive after all sessions.

## Sensory Evaluation

### Training

In all consensus training sessions, participants were given 1.5-ounce samples in opaque, black wine glasses covered with plastic watch glasses and labeled with randomly generated 3-digit codes. Samples were served chilled (5°C) in a sequential monadic order, with 4-6 samples served per training session. Panelists smelled and tasted all samples and were required to expectorate all samples after tasting. Panelists were provided with room temperature spring water and unsalted saltine crackers throughout the study and directed to cleanse their palate between all samples. Panelists were told that they were evaluating cider from Virginia, Vermont, and New York, but were not informed of the nature of specific samples or the purpose of the study.

Panelists participated in 11, 60 to 90-minute training sessions totaling 13 hours of training. In every training session, panelists evaluated 3 to 6 samples ensuring that panelists were exposed to every cider sample at least once during training. Training sessions were carried out in a group setting following the consensus method which has been used extensively for descriptive analysis and lexicon development (Drake and Civille 2003; Lawless and Heymann 2010; Heymann et al. 2014). All training sessions were supplemented with reference

standards for defining a single sensory descriptor, and all members of the panel agreed on each reference standard and its relative intensity. Throughout training, the panel moderator verbally encouraged panelists to “generate terms that they believed to be broadly understandable to most cider consumers.” For example, the suggested term “ethyl acetate” was consolidated into the final descriptor “solvent” because the panelists agreed that the chemical compound term was not an easily understandable *sensory* term.

In the last four training sessions, panelists practiced evaluating samples by rating the intensity of each sensory descriptor using Compusense20 (Compusense, Inc., Guelph, ON, Canada). During these training sessions, panelist performance was monitored by the panel leader, and significant panelist differences were discussed and consensus ratings were agreed upon. Based on these sessions, the panel requested to use structured intensity scales, including two numerical values at respective points on the scale (‘5’ and ‘10’). Though structured line scales have been discouraged in sensory studies (Galvez and Resurreccion 1990; Ledahudec et al. 1992) panelists used structured line scales during group discussions to achieve consensus with their intensity ratings (e.g., “Sample 199 is about a 5 for sour”). The final set of descriptors and verbal definitions agreed upon by the panel is supplied in *Table 2*.

### Evaluation

Data collection was carried out in individual sensory booths in standard conditions as described by Lawless and Heymann (2010). The main exception to generic DA practice was in order to avoid loss of carbonation in samples without wasting a financially untenable amount of sample: on each evaluation day, the same cider samples were evaluated by all panelists. Samples were transferred to a 1 L, glass, screw-top bottle to prevent $CO_2$ loss over the course of the evaluation day. All samples were served chilled (5°C) and kept in the refrigerator (5°C). Each evaluation session lasted a total of three hours, with panelists able to schedule a session during this period. The above procedure was adapted from a procedure for sparkling-wine evaluation developed by Hood White and Heymann (2015).

Panelists evaluated each sample in duplicate using the terms generated from the consensus training phase. Six samples were evaluated during each session, for a total of 14, 60-minute evaluation sessions. Formal evaluation sessions were conducted once per day, three to five days per week, over the course of 6 weeks. All panelists were required to smell and taste the references defined during panelist training before each evaluation session, and panelists were provided a hard copy of *Table 2* to review while practicing with the reference standards before their evaluation sessions. At the request of the panel, panelists were also provided a blank sheet of paper and a pencil during each evaluation session to record their thoughts and experiences as they evaluated the cider samples.

Samples were randomized for each evaluation session according to a Latin Square design (see *Supplementary Material II* for presentation order) within the limitations imposed by the need to serve all panelists the same samples in each session. During each evaluation, samples were presented to panelists in a sequential, monadic design. Samples were served in the same order to all panelists for each session. Panelists were instructed to smell and taste samples, and to rate each sample for each descriptor on a 9-cm line scale, anchored with “None” on the left end and “Very High” on the right end. The line scale was structured with endpoints of 0 (far left), 15 (far right), 5 and 10 at their respective spatial points on the scale, at

the request of the panel. All data was collected with Compusense20 (Compusense, Inc., Guelph, ON, Canada). All procedures and methods for this study were approved by the Virginia Tech Institutional Review Board (IRB #20-527). Subjects gave their informed consent for participation.

### Data Analysis

The DA results were analyzed using 3-way (*panelist x replication x <factor>*) multivariate analyses of variance (MANOVA) to determine overall significant differences in sensory profile ($p < 0.05$) across each of the following factors: cider samples, location (state) of production, cider style, and packaging format. Subsequently, three-way univariate analyses of variance (ANOVA; *panelist x replication x <factor>)* were conducted for each of the sensory attributes (*Table 2*) to identify variation from the same factors: cider samples, location (state) of production, styles, and packaging. A pseudomixed model, suggested by Heymann et al. (2014, p. 19), was used to test whether variation for each factor was still significant after accounting for interactions between the factor and blocking factors (*replication* or *panelist*). Radar plots were created to visualize sensory differences across the significant attributes, as well as to highlight sensory differences across the factors described above. Multivariate results were further analyzed using principal components analysis (PCA) to visualize relationships among the cider samples, the significant attributes, and among ciders made with specific apple varieties. All data was analyzed using RStudio ver. 4.1.2 (R Core Team 2018). Code and data are available from the corresponding author upon reasonable request.

Because of the large number of samples used in the study and subsequent time requirements requested of the sensory panelists, three individual panelists missed one evaluation session each. Simple missing data imputation was adapted from (Heymann et al. (2014, p. 18) and Beale and Little (1975).

## *Results and Discussion*

### Overall Sensory Results

Panelists generated 33 total terms (17 aroma terms, 11 taste terms, 5 mouthfeel terms) using consensus-derived reference standards (see *Table 2*) to describe the cider samples. During sample evaluation, three panelists missed three evaluation sessions for a total of 594/22176 missing attribute-intensity evaluations. This accounts for 2.6% of the data, which was below the threshold for acceptability (5%) recommended by Heymann et al. (2014). To impute missing data, the average of all other panelists' intensity rating for each attribute, for that given sample and replication were used.

Results of the MANOVA tests indicated significant variation in the sensory profiles of the cider samples (Wilk's $\Lambda = 0.0002$, $p < 0.05$). A three-way pseudomixed ANOVA test that accounted for significant panelist and sample interaction (due to high panelist variability) was conducted, resulting in 29 sensory attributes that were found to significantly vary across the cider samples. A mean intensity table (with standard error measures) for all cider samples and significant attributes is provided in *Supplementary Material I*. Multivariate analyses using PCA

(on the correlation matrix) visualize correlations among sensory attributes and the cider samples, as shown in *Figure 1a and 1b*. The first (PC1) and second (PC2) dimensions account for 52.26% of the variation among the samples and descriptive sensory attributes. In both figures, attributes and cider products that are plotted closer together are more similar. For example, the terms “Dirty Sponge”, “Barnyard/Leather”, and “Moldy” are very closely correlated, suggesting that while such terms may be specific, they correspond to a broader descriptive term such as “funky.” As well, terms like “vinegary”, “puckering”, “sour”, and “citrus” clustered closely in the positive direction of PC1, and fruit-related terms clustered in the negative direction of PC1. *Figure 1b* plots the cider samples into the PCA space and highlights the diversity of sensory profiles among the samples, which were segmented into six groups based on their sensory similarity using hierarchical clustering. In comparing both *Figure 1a* and *Figure 1b,* samples such as Windfall Orchard Farmhouse, Shacksbury Deer Snacks IV and Blue Bee Charred Ordinary are associated with “citrus”, Bold Rock Premium Dry is associated with “apple”, Woodchuck Amber is associated with fruity terms (e.g. “apricot”, “dark fruit”), “sweet”, and “caramelized sugar”, and New York Co. Scrappy Dog, Orchard Hill 2019 Northern Spy, and Courthouse Creek 2019 Revival are associated with funky terms (e.g. “dirty sponge (mildew)”, “barnyard/leather”, “moldy”), “smokey”, and “oaky.”

Several of the descriptive terms generated from the current panel that significantly distinguish the cider samples are similar to terms used in other sensory analyses with American cider from the US. For example, Littleson et al. (2022) includes the terms “chemical,” “alcohol,” and “nail polish remover," all of which culminate to form the current panel’s definition of “solvent” (see *Table 2*). More researchers have also utilized diverse sweetness-related terms such as “candied,” “maple syrup,” and “honey” to describe different types of sweetness in cider products (Phetxumphou et al. 2020; Kessinger et al. 2020), which are similar to the current panel’s use of “caramelized sugar,” “candy,” and “sweet.” This consistency across various studies in the terms used to describe the sensory space of cider from the US is valuable for developing a sensory lexicon that is relevant to industry needs.

*Figure 2* uses hierarchical clustering to identify sets of cider products that are similar based on the mean intensity ratings of sensory attributes that significantly varied across the cider products. *Figure 2a* separates all 42 cider samples used in the present study into 6 groups. *Figure 2b* is a radar plot of mean intensity ratings to showcase the representative sensory qualities of the six groups, where the same colors are shared across sub-plots (*a*) and (*b*) as well as *Figure 1*. These plots suggest that the dark red cluster (Group 1) of samples is distinguished by higher average intensity ratings for “astringent”, “barnyard/leather”, “bitter”, “vinegary”, “dirty sponge (mildew)”, “lingering”, and “puckering” attributes. The bright green cluster (Group 3) of samples is distinguished by moderate intensity “sour”, “puckering”, “fizzy”, “lingering”, and “citrus” attributes and lower average intensity ratings for “astringent”, “barnyard”, and “bitter” attributes. The dark yellow and sage-green clusters (Groups 2 and 5) are distinguished by higher average intensity ratings for “sweet”; however, Group 2 has comparably higher mean intensity ratings for “rotten eggs (sulfuric)” and “barnyard/leather”. Results of the hierarchical clustering relevant to intrinsic sensory characteristics are also described in *Table 3*, which summarizes trends in the discrimination of ciders according to the different sensory modalities. Sensory clustering of the cider samples is similar to that of Cole et al. (2022) which

found similar sensory clusters of cider products that were noticeable to trained panelists as well as untrained consumers.

Although sensory similarity is the basis of the hierarchical clustering modeled in *Figure 2a*, the sensory-based clusters also had notable patterns based on extrinsic product factors. For example, Groups 1 and 4 contain mostly single varietal ciders whereas Groups 2, 9, and 5 contain predominantly blended ciders. Though most groups have a mix of traditional style ciders, Groups 2 and 4 predominantly contain modern style cider. Based on *Table 3*, there are not obvious group trends in how cider products cluster based on their geographic origin. How sensory trends vary across extrinsic product factors are further elaborated upon in the following sections. Taken together, *Figures 1* and *2* and *Table 3* highlight the breadth of sensory descriptors for American cider and suggest that broadening cider styles to include more meaningful and specific sensory attributes is relevant for discriminating cider products.

## Extrinsic Product Factor Results

Results of the MANOVA tests (*panelist x replication x <factor>*) across the three remaining, extrinsic factors (location (state) of production, style, packaging) indicated significant variation in the sensory profiles of products from the three states (Wilk's $\Lambda = 0.82884$, $p < 0.05$), significant variation in the sensory profiles across the product styles (Wilk's $\Lambda = 0.59820$, $p < 0.05$), and significant variation in the sensory profiles across product packaging (Wilk's $\Lambda = 0.76098$, $p < 0.05$). Following MANOVA testing, three-way, pseudomixed univariate ANOVA tests were conducted to determine which sensory attributes differed significantly across the states, cider styles, and packaging, while also accounting for panelist interactions. The ANOVA model revealed 11 sensory attributes which significantly varied across the states, and 17 sensory attributes which significantly varied across styles and packaging.

*Figure 3* visualizes the mean intensity ratings of attributes which were significantly different across the three states in a radar plot. Significant variation in the descriptive sensory attributes of cider products from the three states suggest that sensory quality may indeed vary with geographic origin. It is particularly interesting to observe specific sensory differences among the states; where Vermont ciders are significantly more "sour", "apple", and "citrus", Virginia ciders are significantly more "bitter" and "sulfuric", and New York ciders have significantly higher intensities for "sweet", "caramelized sugar", and "buttery." These findings may be due to sample selection effects (as the current study, while large for a DA study, represents only a small random sample of ciders from these states), but they could also indicate broader trends that are relevant for industry stakeholders. Traditionally, cider quality and typicity has been thought to originate from some combination of geographic origin, apple varieties, and production methods (Proulx and Nichols 1980; Lea 2008). American cider products from the US, however, can be made using extremely diverse production methods and types of apples which are not yet tied to geographic regions, and which can have important implications for cider sensory quality (Merwin et al. 2007; Rosend et al. 2019; Littleson et al. 2022). Thus, more research is needed to confirm long-held beliefs about how place also plays into sensory quality, typicity, and *terroir* for American cider specifically (Lea 2008; Brennan 2019; Pucci and Cavallo 2021).

To explore common beliefs (Proulx and Nichols 1980; Lea 2008) and prior research findings on the broad effects of apples varieties on sensory quality (Keller et al. 2004; del

Campo et al. 2006; Nicolini et al. 2018; Rosend et al. 2019; Littleson et al. 2022), *Figure 4* shows the PCA factor plot from *Figure 2b* colored and labeled to highlight single varietal ciders and the apples used to make them. Though cider can be made according to many different production practices which can heavily influence sensory quality, this visualization highlights how ciders made using a blend of apples and those made using only one apple variety can be different. Specifically, many of the single varietal ciders cluster together in the positive direction of PC1, indicative of more sour (e.g. “sour”, “citrus”, “puckering”, “vinegary”), or funky (e.g. “dirty sponge (mildew)”, “moldy”, “barnyard/leather”, “earthy”, “smokey”, “oaky”, “bitter”) flavors, or “astringent”, “puckering” and “burning” mouthfeels (*Figure 1a*), in comparison to more fruit-related and sweet flavors that are associated with ciders made from blends. Littleson et al. (2022) found that single varietal ciders made from Harrison and GoldRush apples had different flavor profiles when made according to different production methods, which is interesting to note in relation to our findings of separation among different cider products made using the same apple varieties in *Figure 4* (e.g., two Harrison single varietal ciders, and two Golden Russet single varietal ciders).

As previously described, the ACA and others (United States Association of Cider Makers 2018; Alexander and Ewing Valliere 2020) have proposed two primary styles: traditional cider or modern cider. For the purposes of this study, ciders were categorized as “modern” or “traditional” from information provided on websites and packaging that either made this declaration explicitly or were inferred by consulting the ACA style guidelines. In the sample set evaluated in this study, we found that almost all traditional ciders were packaged in larger-format (500 mL or larger) glass bottles, whereas almost all modern ciders were packaged in cans (*Table 1*). *Figure 5* highlights sensory differences in the mean intensity ratings of attributes that significantly varied across the cider samples, for both cider styles and cider packaging. Multivariate testing found significant differences in the sensory attributes used to describe traditional versus modern ciders, as well as cider packaging. Further ANOVA testing found 17 attributes which significantly differed across cider styles (i.e., traditional versus modern), as well as across cider packaging (i.e., cans versus bottles).

Modern-style ciders are distinguished by higher average intensities of “sweet”, “apple”, “caramelized sugar”, “candy”, “apricot”, and “dark fruit.” Because these ciders are more likely to be made using apple juice concentrates, higher intensities of sweet-related flavors may be a side-effect of the use of reconstituted apple juice concentrate which has been observed to leave behind residual fructose after fermentation (Rosend et al. 2020). However, higher sweet-related flavors may also be a stylistic choice on behalf of the producer; so, more research is needed to understand these differences. Traditional-style ciders are distinguished by higher average intensities of “sour”, “puckering”, “lingering”, “citrus”, “burning”, “bitter”, “vinegary”, “astringent”, and “solvent.” The large difference in mean intensity ratings for “sweet” across modern and traditional styles (seen in *Figure 5a*) contributes to evidence that a single dryness-sweetness scale for quantifying and describing the sweetness of different styles of cider may be ineffective (Calvert et al. 2022). Also of note, traditional-style ciders have significantly lower mean intensity ratings for “apple” although these products are made with primarily cider-specific apples, suggesting that cider apples and these styles of cider offer unique flavors beyond the classic “apple” flavor. This compliments evidence of cider apples creating products with overall stronger flavor profiles (Thornton 2014; Littleson et al. 2022).

It is important to note that the ACA and other entities define cider styles in terms of flavor and ingredients, with little to no emphasis on production methods. Because cider can be made according to diverse production practices (Proulx and Nichols 1980; Merwin et al. 2007; Lea 2008; Alexander and Ewing Valliere 2020) and because new terms for describing cider based on production methods are becoming more common, more research into the relationship between production methods and sensory quality is imperative.

Because of the potential confound between cider style and packaging observed in this sample set, the sensory profiles of modern and traditional ciders closely parallel sensory attributes that distinguish canned and bottle cider, with the only difference being that “candy” was a significant attribute across the cider styles but was replaced by “buttery” across cider packaging. Empirically, modern-style ciders tend to be in cans and traditional-style ciders tend to be in glass, 750mL or 500mL bottles, which likely explains the close overlap in sensory characteristics across style and packaging. Does this reflect marketing and distribution concerns, or is there a cider-chemistry and flavor reason for this difference? More research is needed to evaluate the true effects of packaging on the sensory profiles and consumer perception and valuation of American cider from the US.

## Limitations and Future Research

In the present study, a key limitation was selection of a representative sample of ciders given the size and diversity of products in the current US cider industry. Because sample selection was limited to products available online and available to be shipped to Blacksburg, VA, USA, the sample set of products used in the present study was limited to those available via distribution channels. This may have caused fewer small and regional brands to be included in the sample set and may have enabled selection of products with similar sensory characteristics. Within sample selection, researchers observed a lack of canned cider available for shipping and because our sampling procedures utilized online shopping formats, the selected ciders may not be cider products which are commonly purchased at cideries or via retail storefronts in the US states of Virginia, Vermont, and New York. This is important because on-site and retail sales of cider products lead the industry, compared to online sales (Wood 2022).

A second limitation was the large sample size (42 samples of cider) and consequently long study timeline (a total of 77 days), which in turn probably contributed to panelists’ variability, as indicated by the significant panelist and sample interactions in M/ANOVA. While significant differences in panelist scale-usage are inevitable (Brockhoff et al. 2015; Pødenphant et al. 2019), it is almost certain that this panel did not detect some sensory differences due to their variability in rating. The panel was still able to find differences in samples for 29/33 consensually defined attributes, indicating the adequacy of the training regimen (Drake and Civille 2003; Lawless and Heymann 2010), but we suspect that other subtle differences would be detected with further training to reduce panelist variability. American cider can present both gross and subtle sensory differences, as evidenced not only by these data but by previous studies (Phetxumphou et al. 2020; Kessinger et al. 2020; Littleson et al. 2022; Cole et al. 2022).

Lastly, the present research produced provocative preliminary evidence of how cider packaging, apple varieties, style, and geographic origin relate to cider sensory quality. Though these factors were not balanced in the current study design, our research found significant differences in how different cider styles, packaging, and geographic origins correlate with

different sensory qualities. Future research should seek to confirm these sensory differences using balanced experimental procedures, as well as investigate consumer preferences for the described sensory parameters. Future research should also seek to investigate how cider sensory quality differs in products outside of the Northeast and Mid-Atlantic regions. It may also be relevant to explore typicity in cider from the interaction of multiple factors, including place and cider production methods. Nonetheless, the present study is valuable for the future development of a sensory lexicon for American cider products that is likely to be understandable to consumers and which may develop a form of sensory objectivity in the American cider marketplace, as has been done by the Wine Aroma Wheel (Noble et al. 1984, 1987; Shapin 2016).

## *Conclusion*

American cider is an increasingly broad and growing market, especially in the Northeast and Mid-Atlantic US. Thus, many researchers and industry stakeholders have aimed to better understand and define the sensory features of American cider. In this study, we identified sensory attributes that can be used to describe a large representative sample of ciders from the US states Virginia, Vermont, and New York, using classical descriptive analysis (DA). This was done to gain a better understanding of the actionable descriptive terms that can be used to describe and discriminate a sample of cider products made in the US. In this study, we also gained preliminary insights into whether a trained panel can significantly distinguish cider samples based on factors such as packaging, apple varieties, and cider style. Lastly, we identified distinct clusters of cider samples based on sensory differences. Overall, modern-style, canned ciders were significantly different from traditional-style, bottled ciders. Sensory quality was also significantly different across cider products from different states, indicating the potential for cider sensory quality to vary based on geography. Though more research is needed to further clarify factors contributing to American cider sensory quality, the results of this research highlight diverse descriptive attributes that can be used to distinguish American cider products produced in the Northeast and Mid-Atlantic US. These findings are meaningful for informing a shared language among cider consumers, producers, and industry stakeholders as the American cider industry moves forward.

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# *Tables*

**Table 3.1.** Cider samples used in the descriptive analysis (DA), including cider producer and product name, location, retail price, and ABV.

| Cider Producer, Product Name | Location | Retail Price (US $) | Packaging | ABV (%) | Single Varietal or Blend | Cider Style |
|---|---|---|---|---|---|---|
| Woodchuck Cidery, Amber | Middlebury (VT) | 1.83 | 12-ounce can/bottle | 5.0 | Blend | Modern |
| Fable Farm Fermentory, 2019 Emanation | Barnard (VT) | 20.00 | 750 mL bottle | 7.75 | Blend | Traditional |
| Flag Hill Farm, Vermont Still Hard Cyder | Vershire (VT) | 11.99 | 750 mL bottle | 8.5 | Blend | Traditional |
| Stowe Cider, High and Dry | Stowe (VT) | 3.25 | 16-ounce can | 6.5 | Blend | Modern |
| Windfall Orchard, Farmhouse Hard Cider | Cornwall (VT) | 15.00 | 500 mL bottle | 9.0 | Blend | Traditional |
| Citizen Cider, Unified Press | Burlington (VT) | 3.00 | 16-ounce can | 5.2 | Blend | Modern |
| Tin Hat Cider, Fipenny Bit | Roxbury (VT) | 12.00 | 500 mL bottle | 7.0 | Blend | Traditional |
| Shacksbury, Deer Snacks IV | Vergennes (VT) | 5.00 | 12-ounce can/bottle | 6.0 | Blend | Traditional |
| Eden Specialty Ciders, Arborealis | Newport (VT) | 28.00 | 750 mL bottle | 7.5 | Blend | Traditional |
| SILO Distillery, Semi-Dry Cider | Windsor (VT) | 5.00 | 16-ounce can | 6.5 | Blend | Modern |
| Champlain Orchards, Crimson Topaz | Shoreham (VT) | 3.25 | 12-ounce can/bottle | 5.8 | Single | Traditional |
| Shelburne Vineyards, Iapetus Cider | Shelburne (VT) | 23.00 | 750 mL bottle | 6.8 | Blend | Traditional |
| Buskey Cider, RVA | Richmond (VA) | 3.25 | 16-ounce can | 5.5 | Blend | Modern |
| Bold Rock Hard Cider, Premium Dry | Nellysford (VA) | 2.15 | 16-ounce can | 6.0 | Blend | Modern |
| Blue Bee Cider, Charred Ordinary | Richmond (VA) | 15.50 | 750 mL bottle | 8.3 | Blend | Traditional |
| Blue Bee Cider, Orchard Potluck (Yarlington Mill) | Richmond (VA) | 16.25 | 750 mL bottle | 8.5 | Single | Traditional |
| Winchester Ciderworks, Malice | Winchester (VA) | 3.25 | 16-ounce can | 6.9 | Blend | Modern |
| Big Fish Cider Company, Wild Meadow | Monterey (VA) | 18.95 | 750 mL bottle | 7.7 | Blend | Traditional |
| Blue Toad Hard Cider, Blue Ridge Blond | Roseland (VA) | 2.74 | 16-ounce can | 4.9 | Blend | Modern |
| Tumbling Creek Cider Company, Ridgerunner Dry | Abingdon (VA) | 18.00 | 750 mL bottle | 7.1 | Blend | Traditional |
| Albemarle Ciderworks, Black Twig | North Garden (VA) | 16.00 | 750 mL bottle | 7.9 | Single | Traditional |
| Albemarle Ciderworks, Royal Pippin | North Garden (VA) | 22.00 | 750 mL bottle | 7.8 | Single | Traditional |
| Potter's Craft Cider, Hewe's Cuvee | Charlottesville (VA) | 22.00 | 750 mL bottle | 9.5 | Single | Traditional |
| Potter's Craft Cider, Dabinett | Charlottesville (VA) | 22.00 | 750 mL bottle | 8.2 | Single | Traditional |
| Potter's Craft Cider, Harrison | Charlottesville (VA) | 22.00 | 750 mL bottle | 8.2 | Single | Traditional |
| Courthouse Creek Cider, 2019 Revival | Maidens (VA) | 20.00 | 750 mL bottle | 9.0 | Single | Traditional |
| Pennings Farm Cidery, Cold Crash | Warwick (NY) | 4.92 | 12-ounce can/bottle | 5.6 | Blend | Modern |
| Angry Orchard Cider Company, Crisp Apple | Walden (NY) | 1.92 | 12-ounce can/bottle | 5.0 | Blend | Modern |

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|---|---|---|---|---|---|---|
| New York Cider Company, Scrappy Dog #2 | Ithaca (NY) | 18.00 | 750 mL bottle | 8.4 | Blend | Traditional |
| Brooklyn Cider House, Half Sour | New Paltz (NY) | 12.00 | 750 mL bottle | 5.8 | Blend | Traditional |
| Rootstock Ciderworks, 2020 Heritage | Williamson (NY) | 17.60 | 750 mL bottle | 6.0 | Blend | Traditional |
| Nine Pin Ciderworks, Signature | Albany (NY) | 11.11 | 650 mL bottle | 6.7 | Blend | Modern |
| Eve's Cidery, 2020 Albee Hill | Van Etten (NY) | 17.00 | 750 mL bottle | 8.4 | Blend | Traditional |
| Bellwether Hard Cider, Liberty Spy | Trumansburg (NY) | 16.00 | 750 mL bottle | 6.8 | Blend | Traditional |
| Redbyrd Orchard Cider, 2020 Workman's Dry | Trumansburg (NY) | 14.00 | 750 mL bottle | 8.2 | Blend | Traditional |
| Westwind Orchard, 2019 NATIVO | Accord (NY) | 23.00 | 750 mL bottle | 8.5 | Single | Traditional |
| Rose Hill Farm, SV3 Ellis Bitter | Red Hook (NY) | 24.00 | 750 mL bottle | 7.7 | Single | Traditional |
| South Hill Cider, Baldwin | Ithaca (NY) | 19.00 | 750 mL bottle | 8.5 | Single | Traditional |
| Orchard Hill Cider Mill, 2019 Northern Spy | New Hampton (NY) | 17.99 | 750 mL bottle | 6.44 | Single | Traditional |
| Embark Craft Ciderworks, 2018 Reserve | Williamson (NY) | 15.00 | 750 mL bottle | 6.9 | Single | Traditional |
| Original Sin Cider, Unfiltered McIntosh | *Unknown* (NY) | 2.25 | 12-ounce can/bottle | 6.0 | Single | Modern |
| Abandoned Cider, GoldRush | Woodstock (NY) | 15.00 | 500 mL bottle | 6.9 | Single | Traditional |

**Table 3.2.** Final list of descriptive terms and reference standards, with verbal description confirmed by panelists and used in descriptive analysis panel.

| Attribute | Reference | Consensus Verbal Description |
|---|---|---|
| *Aroma (Orthonasal)* | | |
| Oaky / Barrel | 20 mL of solution: 7 g oak chips, 250 mL Josh Cellars® Sauvignon Blanc (Deutsch Family Wine & Spirits, Stamford, CT, USA); soaked for four hours | "like a rum or bourbon barrel, aged wine" |
| Smokey | 5 drops liquid smoke (The Colgin Companies, Dallas, TX), 500 mL distilled water | "like campfire must, related to barbeque" |
| Floral | 2 tsp rose water (Ziyad Brand, Cicero, IL), 400 mL distilled water | "like roses or other common flowers" |
| Earthy | 3 sprigs fresh cut grass, 1 tsp soil (Virginia Tech, Blacksburg, VA, USA) | "combination of grassy, mineral, vegetal scents; related to green pepper, moist rocks" |
| Metallic | *(verbal definition)* rubbing together coins on your fingers | "like blood/Iron; also associated with cutting your lip and tasting blood" |
| Citrus | 1 fresh lemon peel, 1 fresh orange peel | "combination of orange, lemon, and lime aromas without the sourness" |
| Apple | 6 g Honeycrisp apple; diced | "smell of fresh apples; also related to smell of an autumn orchard or apple-scented products" |
| Overripe Fruit | 1/4 bruised apple, 1 Sunsweet® dried prune (Sunsweet® Growers, Stockton,CA, USA); ripped into 2 pieces | "related to extremely ripe, almost cooked fruity flavor but not moldy or rancid" |
| Solvent | 20 mL of solution: 50 mL Luksusowa vodka (Wyborowa S.A., Poland), 0.5 mL Kroger® Brand nail polish remover (100% Acetone) (The Kroger Co., Cincinnati, OH, USA), 0.5 mL Kroger® Brand glass cleaner (The Kroger Co., Cincinnati, OH, USA), 100 mL distilled water | "combination of alcohol, cleaner, acetone, ethyl acetate, nail polish aromas" |
| Latex / Rubber | 2x1 inch piece of medical latex glove | "related to plastic-y aromas" |
| Yeasty | ¼ tsp Fleischmann's® Rapidrise instant yeast (Fleischmann, Heilsbronn, Germany), 250 mL distilled water, 1 tsp granulated sugar (The Kroger Co., Cincinnati, OH, USA) | "bread-y like aroma" |
| Barnyard / Leather | 10 mL Oude Geuze Lambic Ale Cuvée René (Brouwerij Lindemans, Vlezenbeek, Belgium) | "funky; related to animal, horse, mouse, leather" |
| Moldy | 1 tsp Murray's® French Roquetfort cheese (The Kroger Co., Cincinnati, OH, USA) | "funky; not animal related" |
| Cinnamon | 1 bag ®Celestial Seasonings Cinnamon Apple Spice tea (®Celestial Seasonings, Inc., The Hain Celestial Group, Inc., Boulder, CO, USA, 250 mL distilled water, 1/8 tsp ground cinnamon (The Kroger Co., Cincinnati, OH, USA); steeped 5 minutes | "explicit fresh cinnamon aroma" |
| Rotten Eggs (sulfuric) | 1 tsp hard-boiled egg (The Kroger Co., Cincinnati, OH, USA); finely crushed | "explicit egg smell" |
| Dirty Sponge (mildew) | 1x1x1 inch piece used, moist kitchen sponge | "related to mildew-y, slightly soapy aroma" |
| Candy | ½ crushed Spangler® Circus Peanut (Spangler® Candy Company, Bryan, OH, USA), ½ piece of Dubble Bubble bubble gum (®Concord Brands, ULC, Tootsie Roll Ind., LLC, Chicago, IL, USA), 1 blue Jolly Rancher (The Hershey Company, Hershey, PA, USA) | "Circus Peanuts, bubblegum candy aromas; also slightly artificial sweet smell" |
| *Flavor (Retronasal)* | | |
| Sour | 20 mL of solution: 1.5 g citric acid, 250 mL distilled water | "like a Sour Patch candy or lemon; not vinegar-like" |

| | | |
|---|---|---|
| Bitter | 20 mL Founders 4 Giants Imperial IPA (Founders Brewing, Grand Rapids, MI, USA) | "like extra dark chocolate, coffee, a very hoppy beer; comes on the palate slightly after swallowing" |
| Sweet | 6 g Kroger® Brand granulated sugar (The Kroger Co., Cincinnati, OH, USA), 100 mL distilled water | "plain sugar-sweetness" |
| Buttery | 15 mL Butter Barefoot® Chardonnay wine (E. & J. Gallo Winery, Modesto, CA, USA) | "explicit butter flavor" |
| Vinegary | 20 mL of solution: 40 mL Great Value™ apple cider vinegar (Walmart Apollo, LLC, Bentonville, AR, USA), 250 mL distilled water | "explicit vinegar-like flavor" |
| Dark Fruit | 10 mL Juicy Juice® Cherry (Juicy Juice®, Harvest Hill Beverage Company, USA), 10 mL RW Knudsen Family® Just Blueberry juice (©Knudsen & Sons, Inc., The J.M. Smucker Company, USA) | "flavor of dark berries or other fruits such as blackberry, cherry, strawberry, plum etc." |
| Pear | 3 pieces of Kroger® Brand diced pears (artificial sweetened, packed in water) (The Kroger Co., Cincinnati, OH, USA) | "explicit fresh pear flavor" |
| Grape | 2 red table grapes; sliced in half | "explicit fresh grape flavor" |
| Apricot | 1 tsp Bonne Maman® Apricot Preserves (Andros Foods USA, Inc., Rye, NY, USA) | "explicit apricot flavor" |
| Lingering | 20 mL Founders 4 Giants Imperial IPA (Founders Brewing, Grand Rapids, MI, USA) | "stays on your palate for a while after swallowing" |
| Caramelized Sugar | 20 mL of solution: ½ cup Kroger® Brand granulated sugar (lightly caramelized) (The Kroger Co., Cincinnati, OH, USA), 500mL water | "slightly burnt sugar flavor; reminiscent of roasted marshmallows and other rich-sugar flavors such as caramel, honey, brown sugar, and molasses" |
| *Mouthfeel* | | |
| Fizzy | 20 mL La Croix® Sparkling Water Pure (© LaCroix Beverages, Inc., National Beverage Corp., Fort Lauderdale, FL, USA) | "in-your-face, big bubbles; small bubbles and slight effervescence is in the middle of the scale" |
| Astringent | 20 mL RW Knudsen Family® Just Pomegranate juice (©Knudsen & Sons, Inc., The J.M. Smucker Company, USA) | "gripping, waxy experience in the mouth; like drinking chapstick" |
| Thick | 15 mL Guinness™ Draught Stout (nitrogenated) (Guinness & Co., Dublin, Ireland) | "viscous sensation in throat during swallowing; slight film left on mouth" |
| Puckering | 10 mL fresh lemon juice, 40 mL distilled water | "pinching/squeezing of mouth; occurring with intense sourness, but also with any other harsh flavors" |
| Burning | 11 mL Luksusowa vodka (Wyborowa S.A., Poland), 25 mL distilled water | "hot, strong feeling towards back of the mouth and up back of the nose, primarily associated with alcohol burn" |

**Table 3.3.** Summary of extrinsic and intrinsic factors which comprise the six sensory-based clusters generated through hierarchical clustering. The number in parenthesis after each factor indicates how many cider samples were described by that factor characteristic. The "strongest sensory descriptors" and "weakest sensory descriptors" refer to the sensory descriptors with the highest mean intensity rating and lowest mean intensity rating, respectively, for each sensory cluster.

| Hierarchical Cluster | Packaging Formats | Geographical Origin | Blend vs. Single Varietal | Cider Style | Strongest Sensory Descriptors | | |
|---|---|---|---|---|---|---|---|
| | | | | | *Sensory Modality* | | |
| | | | | | *Flavor* | *Aroma* | *Mouthfeel* |
| *Group 1* | Bottle (9) | Vermont (1)<br>New York (5)<br>Virginia (3) | Blend (3)<br>Single Varietal (6) | Traditional (9) | Sour<br>Lingering | Solvent<br>Barnyard/Leather | Fizzy<br>Puckering |
| *Group 2* | Can (5)<br>Bottle (2) | Vermont (1)<br>Virginia (3)<br>New York (3) | Blend (6)<br>Single Varietal (1) | Traditional (1)<br>Modern (6) | Sweet<br>Lingering | Apple<br>Barnyard/Leather | Thick<br>Fizzy |
| *Group 3* | Can (2)<br>Bottle (9) | Vermont (6)<br>New York (2)<br>Virginia (2) | Blend (9)<br>Single Varietal (2) | Traditional (10)<br>Modern (1) | Sour<br>Lingering | Apple<br>Solvent | Fizzy<br>Puckering |
| *Group 4* | Can (1)<br>Bottle (5) | Vermont (2)<br>New York (1)<br>Virginia (3) | Blend (2)<br>Single Varietal (4) | Traditional (5)<br>Modern (1) | Lingering<br>Bitter | Apple<br>Solvent | Astringent<br>Thick |
| *Group 5* | Can (3)<br>Bottle (2) | Vermont (1)<br>New York (3)<br>Virginia (1) | Blend (5) | Traditional (1)<br>Modern (4) | Sweet<br>Caramelized Sugar | Apple<br>Candy | Fizzy<br>Thick |
| *Group 6* | Can (1)<br>Bottle (3) | Vermont (1)<br>New York (2)<br>Virginia (1) | Blend (3)<br>Single Varietal (1) | Traditional (4) | Sour<br>Lingering | Apple<br>Candy | Fizzy<br>Astringent |

# *Figures*

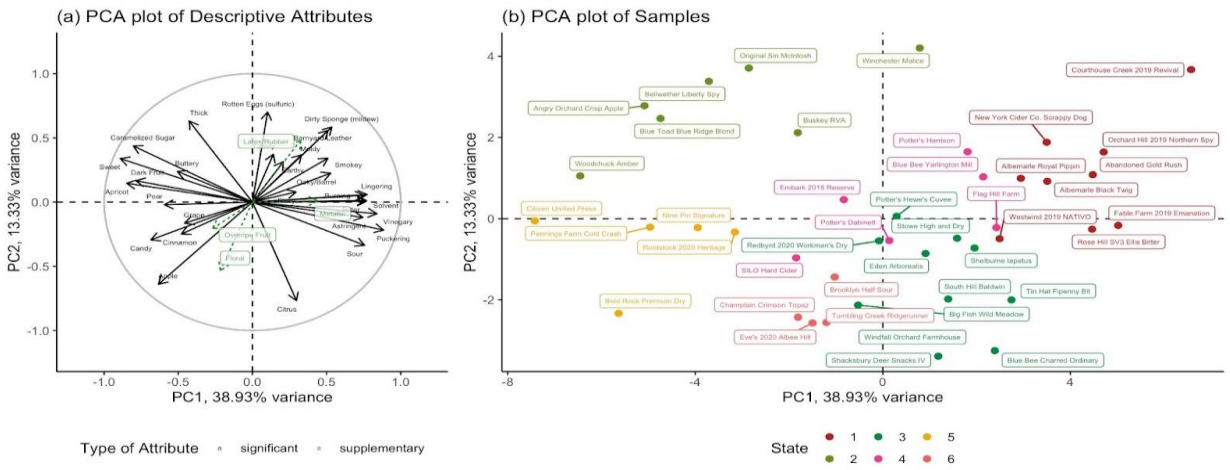


**Figure 3.1.** Principal component analysis (PCA) plots showing (a) significant and non-significant descriptive attributes ("loadings") that varied across the cider samples using 3-way ANOVA, and (b) the separation of cider samples ("factor") based on sensory profile and coloring based on geographic origin ("factor"). In subplot (a), descriptive sensory attributes are visualized as correlations, where closely correlating descriptors are close together and longer vectors are more relevant for describing and differentiating the cider products. In subplot (b), samples that cluster near each other are similar and areas on the plot can be further understood in terms of subplot (a). For example, samples clustered in the positive space of the first dimension, the negative space of the second dimension, and close to the right of the vertical axis are closely correlated with "citrus".

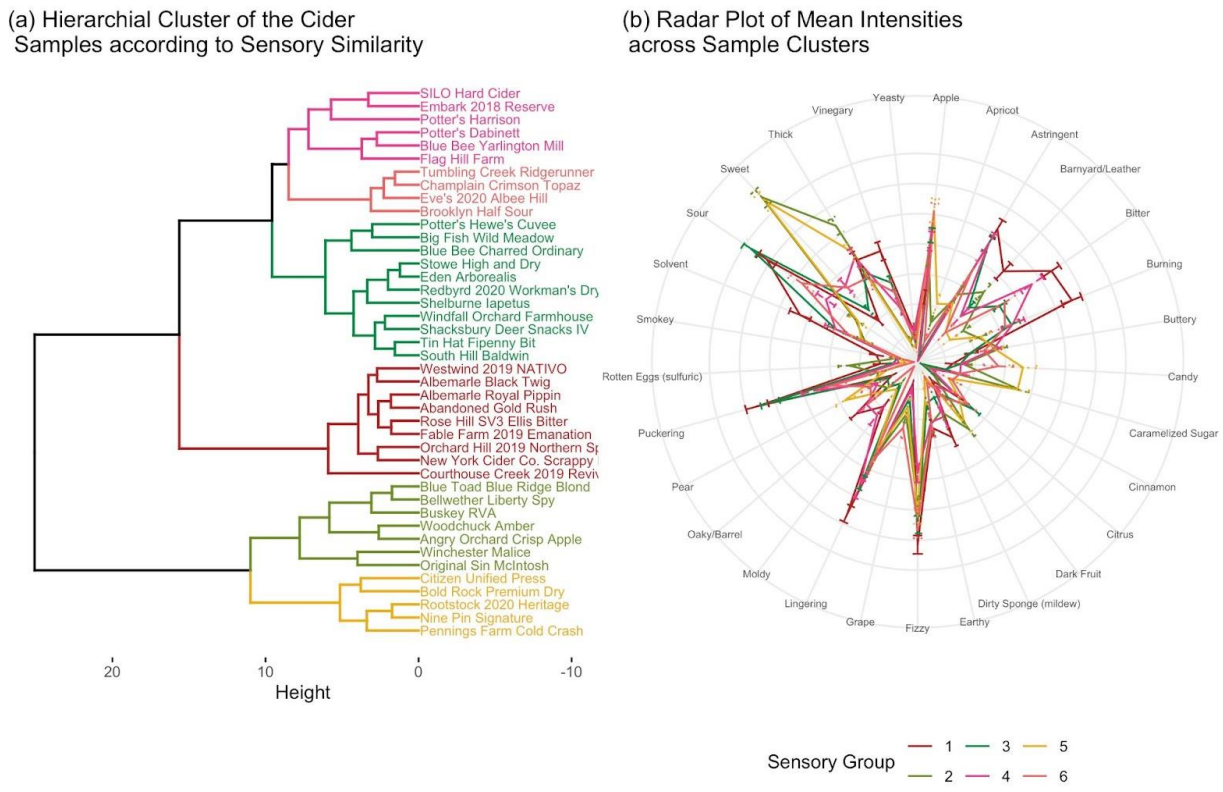


**Figure 3.2.** (a) Hierarchical clustering of cider samples based on sensory similarities, and (b) radar plots showing the mean intensity ratings of sensory attributes that varied significantly across the samples by 3-way ANOVA. Together, these plots visualize sensory groupings which may be valuable for segmenting cider products according to their sensory similarities in future consumer-oriented research.

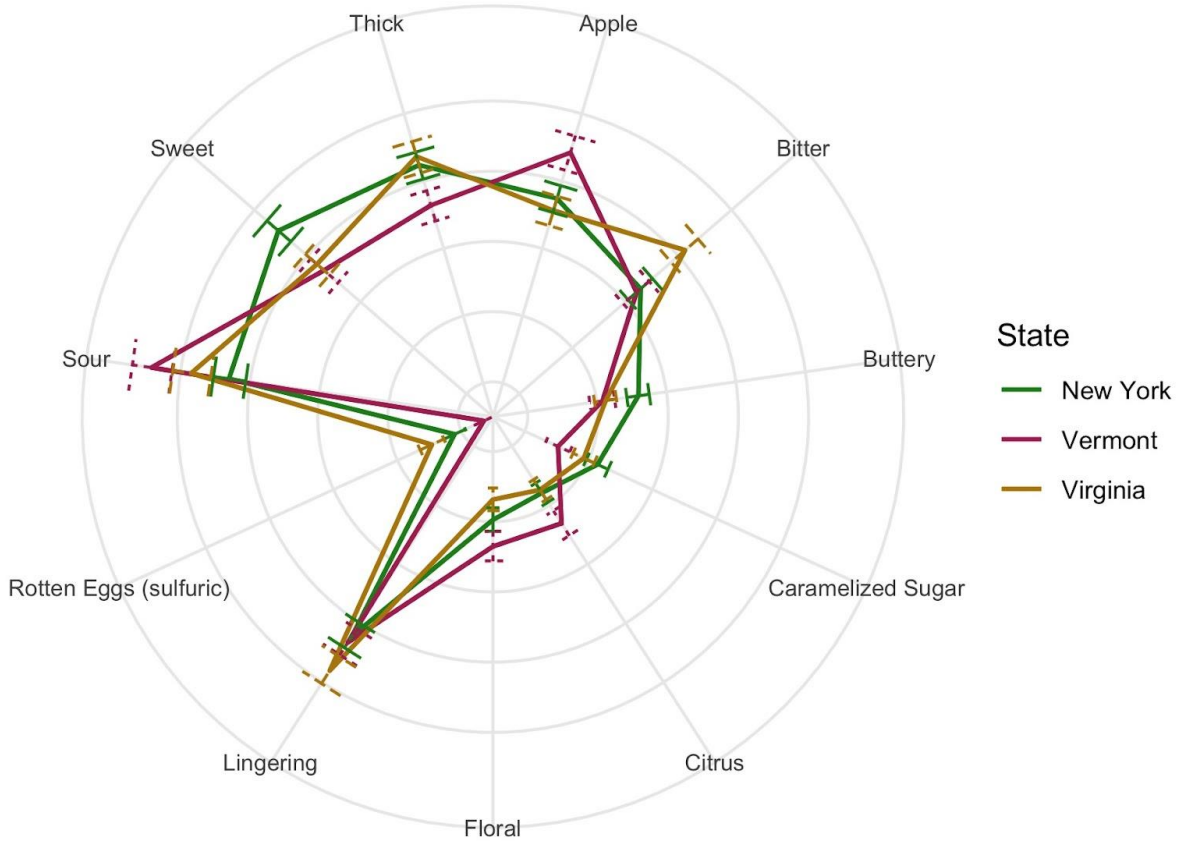


**Figure 3.3.** Radar plots showing differences in mean intensity ratings for sensory attributes that varied significantly across the states. These results visualize subtle yet meaningful differences in the cider sensory quality across the states.

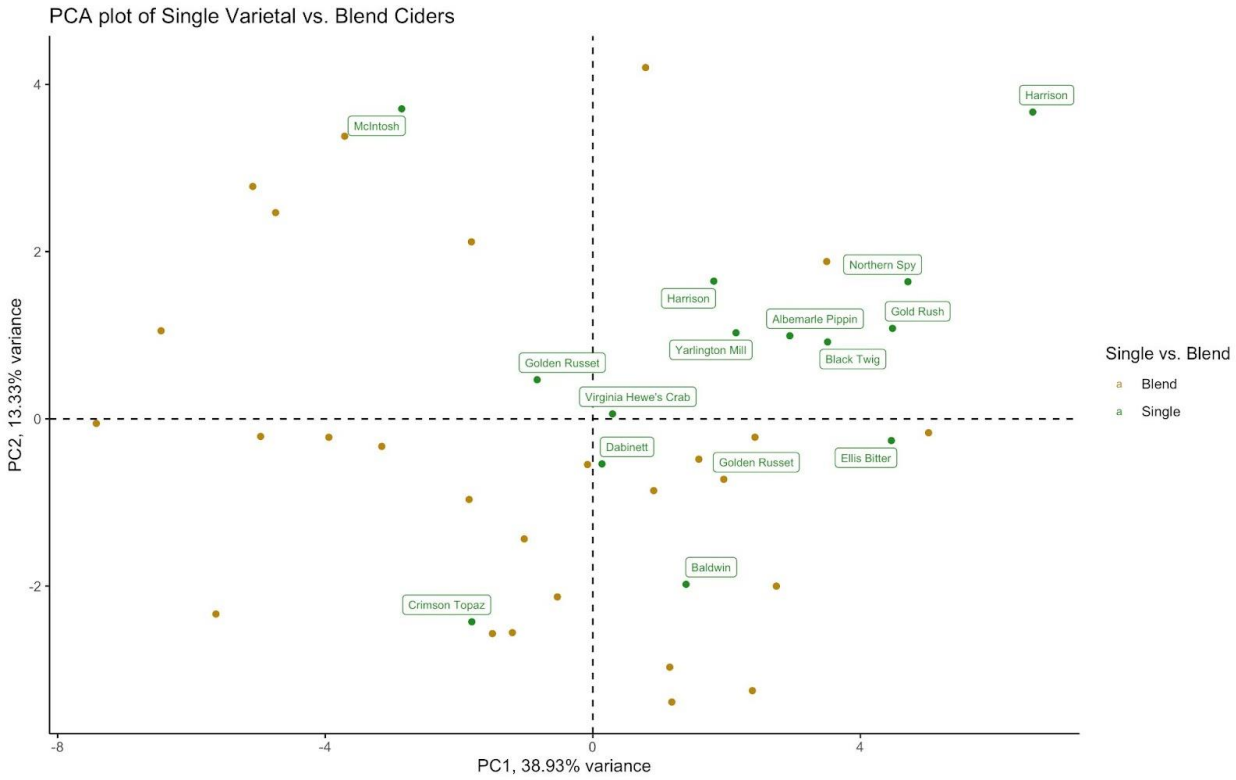


**Figure 3.4.** Principal component analysis (PCA) of cider samples ("factor") based on sensory descriptors and colored to highlight differences across single varietal and blend cider products. Labels indicate apple varieties used in the single varietal samples.

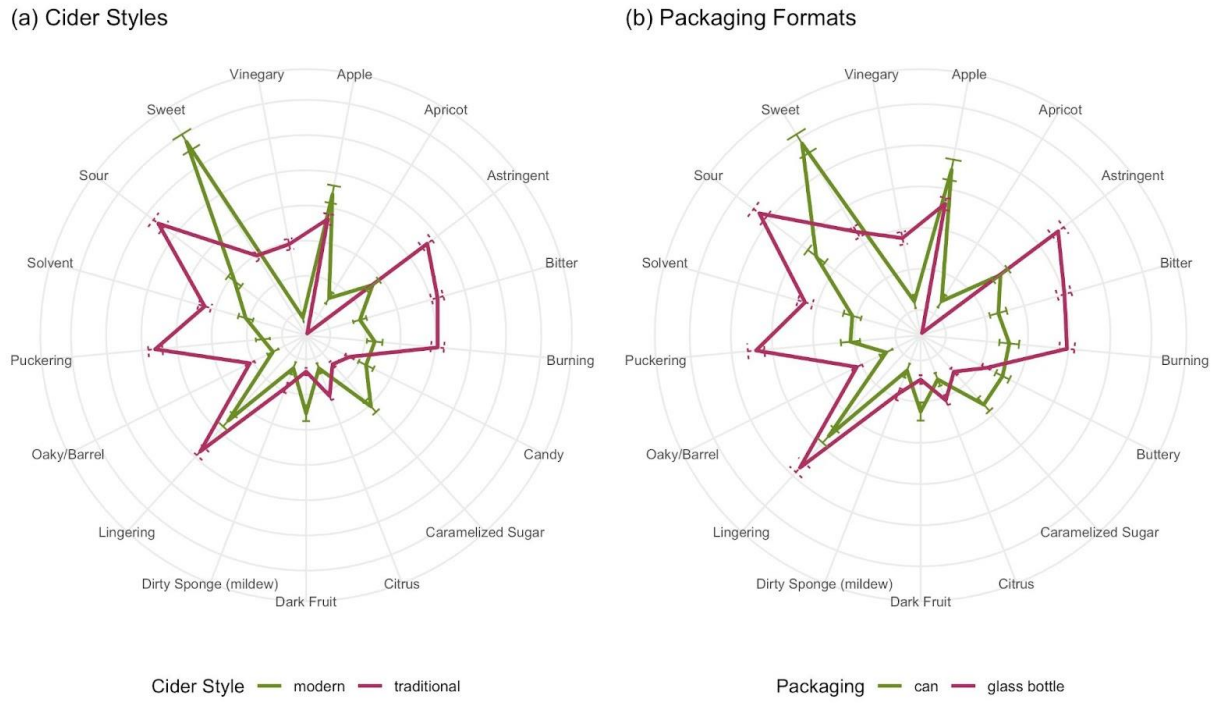


**Figure 3.5.** Radar plots showing differences in mean intensity ratings for sensory attributes that varied significantly across cider styles (traditional and modern) in subplot (a), and across cider packaging (can and glass bottle) in subplot (b), by 3-way ANOVA. Broad differences can be seen across the different types of cider styles and packaging. Modern and canned ciders tend to be more correlated with rich (e.g., “sweet”, “caramelized sugar”, “buttery”, “candy”) and fruity flavors (e.g., “dark fruit”, “apple”), whereas traditional and bottled ciders tend to be more correlated with acidic (e.g., “puckering”, “sour”, “vinegary”, “citrus”), alcohol (e.g., “solvent”, “burning”), and tannin-related descriptors (e.g., “astringent”, “bitter”).

# *Supplementary Material*

## Supplementary Material I

Means and Standard Errors (SE) for descriptors found to be significant by pseudomixed ANOVA. Samples with the same Group letters are not significantly different by Tukey's Honestly Significant Difference (HSD) test.

| | Apple | | Apricot | | Astringent | | Barnyard/Leather | |
|---|---|---|---|---|---|---|---|---|
| **Sample Name** | **Mean ± SE** | **Group** | **Mean ± SE** | **Group** | **Mean ± SE** | **Group** | **Mean ± SE** | **Group** |
| Abandoned Gold Rush | 3.03 ± 0.7 | bcdefgh | 0.03 ± 0.03 | c | 5.6 ± 1.07 | abcd | 3.99 ± 1 | abcde |
| Albemarle Black Twig | 1.75 ± 0.55 | efgh | 0.46 ± 0.35 | bc | 6.18 ± 1.05 | abc | 2.77 ± 0.89 | bcdef |
| Albemarle Royal Pippin | 2.22 ± 0.64 | cdefgh | 0.17 ± 0.1 | bc | 4.35 ± 1.04 | abcde | 2.42 ± 0.88 | cdef |
| Angry Orchard Crisp Apple | 4.13 ± 0.92 | abcdefg | 1.81 ± 0.71 | abc | 2.74 ± 0.69 | cde | 2.76 ± 1 | bcdef |
| Bellwether Liberty Spy | 3.21 ± 0.85 | abcdefgh | 1.89 ± 0.62 | abc | 2.29 ± 0.6 | de | 3.64 ± 0.72 | abcdef |
| Big Fish Wild Meadow | 5.61 ± 0.65 | ab | 0.32 ± 0.31 | bc | 4.5 ± 0.89 | abcde | 1.46 ± 0.63 | def |
| Blue Bee Charred Ordinary | 4.12 ± 0.73 | abcdefg | 0.66 ± 0.59 | bc | 6.71 ± 1.21 | ab | 0.92 ± 0.64 | def |
| Blue Bee Yarlington Mill | 3.48 ± 0.65 | abcdefgh | 0.06 ± 0.04 | c | 5.45 ± 0.99 | abcd | 2.85 ± 0.87 | bcdef |
| Blue Toad Blue Ridge Blond | 4.18 ± 0.8 | abcdefg | 1.92 ± 0.67 | abc | 2.4 ± 0.67 | de | 3.02 ± 1.02 | bcdef |
| Bold Rock Premium Dry | 6.42 ± 0.8 | a | 2.35 ± 0.81 | ab | 1.66 ± 0.6 | e | 0.59 ± 0.53 | ef |
| Brooklyn Half Sour | 4.51 ± 0.94 | abcdefg | 1.3 ± 0.73 | bc | 3.16 ± 0.81 | bcde | 2.04 ± 0.89 | cdef |
| Buskey RVA | 3.06 ± 0.89 | bcdefgh | 1.06 ± 0.41 | bc | 2.56 ± 0.72 | cde | 3.78 ± 0.81 | abcdef |
| Champlain Crimson Topaz | 4.86 ± 0.98 | abcde | 0.59 ± 0.37 | bc | 2.31 ± 0.67 | de | 1.55 ± 0.58 | cdef |
| Citizen Unified Press | 5.31 ± 1.09 | abc | 3.59 ± 0.9 | a | 3.03 ± 0.83 | bcde | 2.44 ± 1.02 | cdef |
| Courthouse Creek 2019 Revival | 0.58 ± 0.28 | h | 0.06 ± 0.06 | c | 5.43 ± 1.02 | abcd | 6.91 ± 1.1 | a |
| Eden Arborealis | 3.95 ± 0.63 | abcdefg | 0.04 ± 0.03 | c | 2.76 ± 0.85 | cde | 1.16 ± 0.47 | def |
| Embark 2018 Reserve | 4.61 ± 0.84 | abcdef | 0.11 ± 0.07 | c | 4.62 ± 0.89 | abcde | 1.14 ± 0.6 | def |
| Eve's 2020 Albee Hill | 5.12 ± 0.82 | abcd | 0.99 ± 0.56 | bc | 4.93 ± 0.9 | abcde | 1.83 ± 0.71 | cdef |
| Fable Farm 2019 Emanation | 2.92 ± 0.98 | bcdefgh | 0.03 ± 0.01 | c | 6.69 ± 1.07 | ab | 6.24 ± 1.32 | ab |
| Flag Hill Farm | 4.53 ± 0.71 | abcdefg | 0.01 ± 0.01 | c | 5.26 ± 0.75 | abcde | 2.47 ± 1.12 | cdef |
| New York Cider Co. Scrappy Dog | 2.11 ± 0.54 | cdefgh | 0.29 ± 0.25 | bc | 3.7 ± 1.05 | bcde | 7.08 ± 0.88 | a |
| Nine Pin Signature | 4.88 ± 0.83 | abcde | 1.52 ± 0.62 | abc | 2.48 ± 0.64 | cde | 2.22 ± 0.89 | cdef |
| Orchard Hill 2019 Northern Spy | 1.27 ± 0.48 | gh | 0.06 ± 0.04 | c | 4.76 ± 0.97 | abcde | 3.8 ± 0.89 | abcdef |
| Original Sin McIntosh | 3.44 ± 0.66 | abcdefgh | 1.57 ± 0.64 | abc | 2.95 ± 0.81 | cde | 4 ± 0.79 | abcde |
| Pennings Farm Cold Crash | 5.84 ± 0.83 | ab | 2.22 ± 0.64 | abc | 1.93 ± 0.72 | de | 0.58 ± 0.37 | ef |
| Potter's Dabinett | 5.19 ± 0.89 | abcd | 0.05 ± 0.03 | c | 5.39 ± 0.91 | abcd | 1 ± 0.6 | def |
| Potter's Harrison | 2.01 ± 0.54 | defgh | 0.17 ± 0.09 | bc | 4.35 ± 0.85 | abcde | 5.22 ± 1.06 | abc |
| Potter's Hewe's Cuvee | 4.52 ± 0.92 | abcdefg | 0.65 ± 0.32 | bc | 7.53 ± 1.13 | a | 2.52 ± 0.71 | cdef |
| Redbyrd 2020 Workman's Dry | 3.39 ± 0.61 | abcdefgh | 0.5 ± 0.37 | bc | 4.68 ± 0.76 | abcde | 2.28 ± 1.16 | cdef |
| Rootstock 2020 Heritage | 3.21 ± 0.79 | abcdefgh | 0.88 ± 0.42 | bc | 2.5 ± 0.81 | cde | 1.44 ± 0.64 | def |
| Rose Hill SV3 Ellis Bitter | 3.76 ± 0.78 | abcdefgh | 0.06 ± 0.03 | c | 5.26 ± 0.86 | abcde | 2.51 ± 0.76 | cdef |
| Shacksbury Deer Snacks IV | 5.21 ± 0.85 | abcd | 0.4 ± 0.35 | bc | 4.53 ± 0.69 | abcde | 2.76 ± 0.92 | bcdef |
| Shelburne Iapetus | 3.42 ± 1 | abcdefgh | 0.72 ± 0.44 | bc | 3.68 ± 0.74 | bcde | 3.79 ± 1.06 | abcdef |
| SILO Hard Cider | 4.84 ± 0.84 | abcde | 0.63 ± 0.4 | bc | 3.05 ± 0.82 | bcde | 0.27 ± 0.17 | f |
| South Hill Baldwin | 4.73 ± 0.74 | abcdef | 0.07 ± 0.04 | c | 4.39 ± 0.9 | abcde | 2.49 ± 0.69 | cdef |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Stowe High and Dry | 3.51 ± 0.89 | abcdefgh | 0.03 ± 0.02 | c | 3.52 ± 0.69 | bcde | 4.36 ± 1.17 | abcd |
| Tin Hat Fipenny Bit | 4.02 ± 0.76 | abcdefg | 0.09 ± 0.07 | c | 5.24 ± 0.91 | abcde | 4.21 ± 0.94 | abcde |
| Tumbling Creek Ridgerunner | 5.28 ± 0.8 | abcd | 0.31 ± 0.18 | bc | 3.8 ± 0.92 | bcde | 0.24 ± 0.2 | f |
| Westwind 2019 NATIVO | 2.61 ± 0.78 | bcdefgh | 0.07 ± 0.04 | c | 5.09 ± 1.05 | abcde | 2.28 ± 1.03 | cdef |
| Winchester Malice | 1.47 ± 0.56 | fgh | 0.45 ± 0.33 | bc | 3.99 ± 1.15 | abcde | 4.14 ± 1.13 | abcde |
| Windfall Orchard Farmhouse | 4.92 ± 0.99 | abcde | 0.11 ± 0.07 | bc | 3.74 ± 1.02 | bcde | 2.11 ± 0.7 | cdef |
| Woodchuck Amber | 5.57 ± 0.72 | ab | 1.49 ± 0.67 | abc | 1.91 ± 0.8 | de | 1.58 ± 0.65 | cdef |

| | Bitter | | Burning | | Buttery | | Candy | |
|---|---|---|---|---|---|---|---|---|
| **Sample** | **Mean ± SE** | **Group** | **Mean ± SE** | **Group** | **Mean ± SE** | **Group** | **Mean ± SE** | **Group** |
| Abandoned Gold Rush | 6.27 ± 0.95 | abc | 6.94 ± 1.2 | a | 4.09 ± 0.62 | a | 1.41 ± 0.95 | abc |
| Albemarle Black Twig | 5.33 ± 0.97 | abcd | 4.67 ± 1.03 | abcdef | 1.8 ± 0.59 | ab | 1.02 ± 0.67 | Bc |
| Albemarle Royal Pippin | 5.31 ± 0.89 | abcd | 4.92 ± 0.84 | abcdef | 1.55 ± 0.5 | ab | 1.8 ± 0.88 | Abc |
| Angry Orchard Crisp Apple | 0.57 ± 0.31 | l | 1.86 ± 0.63 | efg | 2.65 ± 0.73 | ab | 2.64 ± 0.78 | abc |
| Bellwether Liberty Spy | 2.22 ± 0.72 | efghijkl | 2.61 ± 0.96 | cdefg | 2.92 ± 0.66 | ab | 1.19 ± 0.6 | abc |
| Big Fish Wild Meadow | 3.6 ± 0.71 | cdefghijk | 3.01 ± 0.76 | cdefg | 1.57 ± 0.53 | ab | 1.86 ± 0.73 | abc |
| Blue Bee Charred Ordinary | 3.95 ± 0.92 | cdefghij | 2.67 ± 1.04 | cdefg | 1.28 ± 0.57 | b | 2.04 ± 0.75 | abc |
| Blue Bee Yarlington Mill | 7.76 ± 0.93 | a | 4.64 ± 0.98 | abcdef | 2.16 ± 0.58 | ab | 0.86 ± 0.46 | bc |
| Blue Toad Blue Ridge Blond | 0.33 ± 0.12 | l | 2.07 ± 0.56 | efg | 2.27 ± 0.58 | ab | 2.95 ± 1.01 | abc |
| Bold Rock Premium Dry | 1.58 ± 0.52 | hijkl | 2.84 ± 0.95 | cdefg | 2.2 ± 0.57 | ab | 3.22 ± 0.79 | abc |
| Brooklyn Half Sour | 2.41 ± 0.97 | defghijkl | 3.96 ± 1.02 | abcdefg | 1.62 ± 0.52 | ab | 2.94 ± 0.99 | abc |
| Buskey RVA | 3.83 ± 0.84 | cdefghijk | 3.15 ± 0.96 | bcdefg | 2.48 ± 0.6 | ab | 0.98 ± 0.47 | bc |
| Champlain Crimson Topaz | 3.61 ± 0.84 | cdefghijk | 3.98 ± 1.08 | abcdefg | 2.07 ± 0.61 | ab | 2.88 ± 1 | abc |
| Citizen Unified Press | 1.13 ± 0.74 | jkl | 1.53 ± 0.58 | fg | 2.86 ± 0.59 | ab | 4.39 ± 1.2 | a |
| Courthouse Creek 2019 Revival | 5.31 ± 0.9 | abcd | 4.76 ± 0.93 | abcdef | 1.75 ± 0.61 | ab | 0.28 ± 0.23 | c |
| Eden Arborealis | 3.67 ± 0.76 | cdefghijk | 4.38 ± 1.01 | abcdef | 1.26 ± 0.49 | b | 1.19 ± 0.46 | abc |
| Embark 2018 Reserve | 4.62 ± 1.04 | bcdefg | 3.28 ± 0.97 | bcdefg | 3.48 ± 0.8 | ab | 1.62 ± 0.54 | abc |
| Eve's 2020 Albee Hill | 3.79 ± 0.97 | cdefghijk | 1.99 ± 0.9 | efg | 2.99 ± 0.64 | ab | 2.87 ± 1.08 | abc |
| Fable Farm 2019 Emanation | 5.1 ± 0.97 | abcde | 5.41 ± 0.94 | abcde | 1.14 ± 0.39 | b | 1.3 ± 0.73 | abc |
| Flag Hill Farm | 5.02 ± 1.01 | abcdef | 3.96 ± 1.08 | abcdefg | 2.63 ± 0.68 | ab | 1.43 ± 0.54 | abc |
| New York Cider Co. Scrappy Dog | 7.08 ± 0.84 | ab | 5.95 ± 1.03 | abc | 1.39 ± 0.5 | ab | 2.14 ± 1.03 | abc |
| Nine Pin Signature | 0.89 ± 0.28 | kl | 2.24 ± 0.83 | defg | 2.34 ± 0.61 | ab | 3.17 ± 0.96 | abc |
| Orchard Hill 2019 Northern Spy | 5.4 ± 1.07 | abcd | 5.38 ± 1.12 | abcde | 1.62 ± 0.54 | ab | 0.49 ± 0.28 | c |
| Original Sin McIntosh | 1.77 ± 0.54 | ghijkl | 2.11 ± 0.65 | defg | 2.97 ± 0.47 | ab | 1.61 ± 0.65 | abc |
| Pennings Farm Cold Crash | 2 ± 0.54 | fghijkl | 2.84 ± 0.89 | cdefg | 3.18 ± 0.74 | ab | 3.29 ± 0.98 | abc |
| Potter's Dabinett | 6.29 ± 1.08 | abc | 4.76 ± 1.16 | abcdef | 2.85 ± 0.54 | ab | 2.07 ± 0.78 | abc |
| Potter's Harrison | 2.86 ± 0.87 | defghijkl | 2.73 ± 0.93 | cdefg | 1.73 ± 0.52 | ab | 1.26 ± 0.49 | abc |
| Potter's Hewe's Cuvee | 2.76 ± 0.92 | defghijkl | 4.62 ± 1.15 | abcdef | 2.5 ± 0.6 | ab | 1.86 ± 0.61 | abc |
| Redbyrd 2020 Workman's Dry | 1.88 ± 0.52 | ghijkl | 1.97 ± 0.87 | efg | 2.81 ± 0.72 | ab | 2.72 ± 0.76 | abc |
| Rootstock 2020 Heritage | 1.35 ± 0.71 | ijkl | 2.15 ± 0.75 | defg | 2.87 ± 0.62 | ab | 3.88 ± 1.16 | ab |
| Rose Hill SV3 Ellis Bitter | 4.04 ± 0.86 | cdefghij | 5.66 ± 1.01 | abcd | 1.39 ± 0.65 | ab | 1.29 ± 0.63 | abc |
| Shacksbury Deer Snacks IV | 3.19 ± 0.71 | defghijkl | 3.44 ± 1.01 | abcdefg | 1.94 ± 0.56 | ab | 1.11 ± 0.52 | abc |
| Shelburne Iapetus | 1.54 ± 0.61 | hijkl | 4.54 ± 1.06 | abcdef | 1.62 ± 0.57 | ab | 0.98 ± 0.48 | bc |
| SILO Hard Cider | 1.46 ± 0.39 | ijkl | 1.61 ± 0.62 | fg | 2.91 ± 0.87 | ab | 1.9 ± 0.55 | abc |
| South Hill Baldwin | 3.03 ± 0.83 | defghijkl | 4.29 ± 1.13 | abcdef | 2.68 ± 0.65 | ab | 1.82 ± 0.71 | abc |
| Stowe High and Dry | 4.64 ± 0.73 | bcdefg | 3.09 ± 0.86 | cdefg | 1.71 ± 0.62 | ab | 0.44 ± 0.36 | c |
| Tin Hat Fipenny Bit | 4.09 ± 0.97 | bcdefghij | 2.01 ± 0.72 | efg | 1.51 ± 0.6 | ab | 0.79 ± 0.43 | bc |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Tumbling Creek Ridgerunner | 4.49 ± 0.79 | bcdefgh | 2.89 ± 0.8 | cdefg | 2.66 ± 0.81 | ab | 2.41 ± 0.97 | abc |
| Westwind 2019 NATIVO | 5.26 ± 1.15 | abcd | 6.69 ± 1.12 | ab | 2.52 ± 0.6 | ab | 1.54 ± 0.57 | abc |
| Winchester Malice | 4.33 ± 1.05 | bcdefghi | 3.32 ± 0.96 | bcdefg | 2.97 ± 0.65 | ab | 0.64 ± 0.35 | bc |
| Windfall Orchard Farmhouse | 4.76 ± 0.84 | abcdefg | 3.76 ± 1.01 | abcdefg | 1.54 ± 0.5 | ab | 1.71 ± 0.68 | abc |
| Woodchuck Amber | 0.32 ± 0.15 | I | 0.62 ± 0.38 | g | 3.8 ± 0.66 | ab | 1.36 ± 0.72 | abc |

| | Caramelized Sugar | | Cinnamon | | Citrus | | Dark Fruit | |
|---|---|---|---|---|---|---|---|---|
| **Sample** | **Mean ± SE** | **Group** | **Mean ± SE** | **Group** | **Mean ± SE** | **Group** | **Mean ± SE** | **Group** |
| Abandoned Gold Rush | 1.1 ± 0.46 | defgh | 0.03 ± 0.03 | b | 2.33 ± 0.73 | abc | 0.37 ± 0.25 | b |
| Albemarle Black Twig | 1.23 ± 0.5 | defgh | 0.03 ± 0.02 | b | 2.74 ± 0.77 | abc | 1.76 ± 0.53 | ab |
| Albemarle Royal Pippin | 1.3 ± 0.53 | defgh | 0.5 ± 0.45 | ab | 1.81 ± 0.7 | abc | 1 ± 0.47 | ab |
| Angry Orchard Crisp Apple | 3.45 ± 0.82 | abcde | 0.08 ± 0.07 | b | 1.48 ± 0.47 | abc | 3.19 ± 0.74 | ab |
| Bellwether Liberty Spy | 5.49 ± 0.68 | a | 0.68 ± 0.38 | ab | 1.11 ± 0.56 | abc | 2.46 ± 0.8 | ab |
| Big Fish Wild Meadow | 1.1 ± 0.46 | defgh | 0.03 ± 0.02 | b | 2.3 ± 0.74 | abc | 2.69 ± 0.89 | ab |
| Blue Bee Charred Ordinary | 0.89 ± 0.44 | fgh | 0.51 ± 0.47 | ab | 2.68 ± 0.95 | abc | 1.84 ± 0.68 | ab |
| Blue Bee Yarlington Mill | 1.09 ± 0.52 | defgh | 0.64 ± 0.53 | ab | 1.04 ± 0.41 | abc | 0.84 ± 0.43 | ab |
| Blue Toad Blue Ridge Blond | 3.97 ± 0.73 | abc | 0.64 ± 0.43 | ab | 0.64 ± 0.27 | bc | 3.32 ± 0.93 | ab |
| Bold Rock Premium Dry | 3.54 ± 0.83 | abcd | 1.29 ± 0.94 | ab | 3.06 ± 0.74 | ab | 2.94 ± 0.75 | ab |
| Brooklyn Half Sour | 2.13 ± 0.71 | cdefgh | 1.31 ± 0.69 | ab | 2.05 ± 0.71 | abc | 1.93 ± 0.78 | ab |
| Buskey RVA | 2.68 ± 0.58 | bcdefgh | 0.36 ± 0.22 | b | 0.86 ± 0.38 | abc | 1.58 ± 0.65 | ab |
| Champlain Crimson Topaz | 1.23 ± 0.48 | defgh | 1.89 ± 0.78 | ab | 2.41 ± 0.73 | abc | 1.22 ± 0.5 | ab |
| Citizen Unified Press | 4.71 ± 0.96 | ab | 2.31 ± 1.2 | a | 1.19 ± 0.45 | abc | 3.83 ± 1.01 | a |
| Courthouse Creek 2019 Revival | 0.97 ± 0.52 | efgh | 0.03 ± 0.01 | b | 0.86 ± 0.39 | abc | 0.42 ± 0.36 | b |
| Eden Arborealis | 0.98 ± 0.43 | efgh | 0.06 ± 0.04 | b | 2.05 ± 0.77 | abc | 1 ± 0.4 | ab |
| Embark 2018 Reserve | 1.98 ± 0.55 | cdefgh | 0.37 ± 0.25 | b | 0.95 ± 0.39 | abc | 1.47 ± 0.49 | ab |
| Eve's 2020 Albee Hill | 1.47 ± 0.63 | cdefgh | 1.09 ± 0.49 | ab | 1.78 ± 0.59 | abc | 1.56 ± 0.49 | ab |
| Fable Farm 2019 Emanation | 0.95 ± 0.55 | efgh | 0.03 ± 0.01 | b | 2.14 ± 0.68 | abc | 0.63 ± 0.41 | ab |
| Flag Hill Farm | 1.29 ± 0.55 | defgh | 0.01 ± 0.01 | b | 2.75 ± 0.75 | abc | 1.04 ± 0.38 | ab |
| New York Cider Co. Scrappy Dog | 0.84 ± 0.49 | fgh | 0.61 ± 0.44 | ab | 0.76 ± 0.39 | abc | 0.89 ± 0.42 | ab |
| Nine Pin Signature | 3.24 ± 0.87 | abcdefg | 0.59 ± 0.38 | ab | 1.74 ± 0.68 | abc | 2.8 ± 0.75 | ab |
| Orchard Hill 2019 Northern Spy | 0.88 ± 0.47 | fgh | 0.12 ± 0.08 | b | 2.24 ± 0.74 | abc | 0.57 ± 0.28 | b |
| Original Sin McIntosh | 3.3 ± 0.63 | abcdef | 0.27 ± 0.21 | b | 0.58 ± 0.25 | bc | 3.81 ± 0.85 | a |
| Pennings Farm Cold Crash | 2.95 ± 0.73 | bcdefgh | 1.09 ± 0.61 | ab | 1.25 ± 0.58 | abc | 0.98 ± 0.57 | ab |
| Potter's Dabinett | 2.26 ± 0.64 | bcdefgh | 1.78 ± 0.58 | ab | 1.65 ± 0.49 | abc | 0.5 ± 0.36 | b |
| Potter's Harrison | 1.44 ± 0.54 | defgh | 0.81 ± 0.41 | ab | 1.22 ± 0.46 | abc | 1.14 ± 0.43 | ab |
| Potter's Hewe's Cuvee | 1.98 ± 0.52 | cdefgh | 0.38 ± 0.31 | ab | 2.37 ± 0.7 | abc | 2.26 ± 0.81 | ab |
| Redbyrd 2020 Workman's Dry | 0.94 ± 0.42 | efgh | 0.02 ± 0.02 | b | 2.18 ± 0.68 | abc | 2.04 ± 0.57 | ab |
| Rootstock 2020 Heritage | 3.21 ± 0.72 | abcdefg | 0.91 ± 0.42 | ab | 2.14 ± 0.62 | abc | 2.74 ± 0.67 | ab |
| Rose Hill SV3 Ellis Bitter | 0.75 ± 0.42 | gh | 0.31 ± 0.27 | b | 2.86 ± 0.76 | abc | 0.84 ± 0.37 | ab |
| Shacksbury Deer Snacks IV | 0.84 ± 0.42 | fgh | 0.32 ± 0.26 | b | 3.37 ± 0.8 | a | 1.28 ± 0.68 | ab |
| Shelburne Iapetus | 1.59 ± 0.79 | cdefgh | 0.56 ± 0.53 | ab | 2.9 ± 1.04 | abc | 1.21 ± 0.54 | ab |
| SILO Hard Cider | 1.25 ± 0.48 | defgh | 0.04 ± 0.03 | b | 2.66 ± 0.7 | abc | 1.66 ± 0.71 | ab |
| South Hill Baldwin | 1.01 ± 0.43 | efgh | 0.06 ± 0.04 | b | 2.57 ± 1 | abc | 1.66 ± 0.54 | ab |
| Stowe High and Dry | 0.94 ± 0.52 | efgh | 0.02 ± 0.02 | b | 1.41 ± 0.58 | abc | 0.38 ± 0.23 | b |
| Tin Hat Fipenny Bit | 0.52 ± 0.38 | h | 0.42 ± 0.29 | ab | 3.05 ± 0.88 | ab | 1.53 ± 0.7 | ab |
| Tumbling Creek Ridgerunner | 1.4 ± 0.54 | defgh | 1.25 ± 0.77 | ab | 2.83 ± 0.74 | abc | 1.83 ± 0.68 | ab |
| Westwind 2019 NATIVO | 1.51 ± 0.54 | cdefgh | 0.58 ± 0.3 | ab | 2.69 ± 0.79 | abc | 1.21 ± 0.58 | ab |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Winchester Malice | 3.13 ± 0.73 | abcdefg | 0.29 ± 0.27 | b | 0.35 ± 0.26 | c | 2.1 ± 0.64 | ab |
| Windfall Orchard Farmhouse | 0.54 ± 0.34 | h | 0.33 ± 0.25 | b | 3.13 ± 0.69 | ab | 0.43 ± 0.23 | b |
| Woodchuck Amber | 3.44 ± 0.74 | abcde | 0.28 ± 0.24 | b | 0.65 ± 0.3 | bc | 3.79 ± 0.84 | a |

| | Dirty Sponge (mildew) | | Earthy | | Fizzy | | Grape | |
|---|---|---|---|---|---|---|---|---|
| **Sample** | **Mean ± SE** | **Group** | **Mean ± SE** | **Group** | **Mean ± SE** | **Group** | **Mean ± SE** | **Group** |
| Abandoned Gold Rush | 3.39 ± 1.02 | abcde | 2.35 ± 0.97 | ab | 8.16 ± 0.97 | ab | 0.72 ± 0.41 | cd |
| Albemarle Black Twig | 1.91 ± 0.64 | abcde | 1.49 ± 0.66 | ab | 6.12 ± 1.03 | abcdef | 0.89 ± 0.43 | abcd |
| Albemarle Royal Pippin | 2.92 ± 0.96 | abcde | 2.89 ± 0.72 | ab | 4.56 ± 0.85 | cdefghij | 1.23 ± 0.55 | abcd |
| Angry Orchard Crisp Apple | 1.52 ± 0.68 | abcde | 1.81 ± 0.58 | ab | 2.55 ± 0.58 | ghij | 1.48 ± 0.54 | abcd |
| Bellwether Liberty Spy | 3.69 ± 1.18 | abc | 2.33 ± 0.89 | ab | 4.58 ± 0.97 | cdefghij | 0.84 ± 0.42 | abcd |
| Big Fish Wild Meadow | 0.01 ± 0.01 | e | 1.04 ± 0.49 | ab | 4.54 ± 0.83 | cdefghij | 1.44 ± 0.74 | abcd |
| Blue Bee Charred Ordinary | 1.26 ± 0.53 | bcde | 1.21 ± 0.6 | ab | 5.28 ± 1.06 | abcdefgh | 3.54 ± 0.87 | a |
| Blue Bee Yarlington Mill | 1.47 ± 0.72 | abcde | 2.08 ± 0.83 | ab | 5.24 ± 0.74 | abcdefgh | 0.46 ± 0.25 | d |
| Blue Toad Blue Ridge Blond | 1.76 ± 0.64 | abcde | 3.56 ± 0.87 | ab | 5.77 ± 0.68 | abcdefg | 1.38 ± 0.58 | abcd |
| Bold Rock Premium Dry | 0.24 ± 0.23 | de | 0.38 ± 0.26 | b | 6.49 ± 0.8 | abcde | 2.19 ± 0.64 | abcd |
| Brooklyn Half Sour | 0.91 ± 0.39 | bcde | 2.46 ± 1.01 | ab | 7.22 ± 0.87 | abcd | 2.68 ± 0.8 | abcd |
| Buskey RVA | 1.26 ± 0.6 | bcde | 2.16 ± 0.81 | ab | 4.9 ± 0.75 | bcdefghi | 1.66 ± 0.78 | abcd |
| Champlain Crimson Topaz | 0.85 ± 0.34 | cde | 2.11 ± 0.61 | ab | 6.15 ± 0.99 | abcdef | 3.48 ± 0.73 | ab |
| Citizen Unified Press | 0.56 ± 0.31 | cde | 0.84 ± 0.52 | ab | 5.4 ± 0.95 | abcdefgh | 1.49 ± 0.8 | abcd |
| Courthouse Creek 2019 Revival | 4.83 ± 1.2 | a | 1.44 ± 0.71 | ab | 6.64 ± 0.72 | abcde | 0.84 ± 0.5 | abcd |
| Eden Arborealis | 1.91 ± 0.75 | abcde | 1.3 ± 0.6 | ab | 7.36 ± 0.9 | abcd | 1.07 ± 0.49 | abcd |
| Embark 2018 Reserve | 1.07 ± 0.54 | bcde | 2.84 ± 0.81 | ab | 3.42 ± 0.77 | efghij | 1.6 ± 0.55 | abcd |
| Eve's 2020 Albee Hill | 0.44 ± 0.32 | cde | 2.04 ± 0.67 | ab | 1.4 ± 0.45 | j | 1.91 ± 0.63 | abcd |
| Fable Farm 2019 Emanation | 1.42 ± 0.65 | bcde | 2.58 ± 0.97 | ab | 6.12 ± 0.97 | abcdef | 0.69 ± 0.4 | cd |
| Flag Hill Farm | 2.82 ± 0.94 | abcde | 2.01 ± 0.66 | ab | 1.75 ± 0.44 | ij | 1.53 ± 0.69 | abcd |
| New York Cider Co. Scrappy Dog | 2.43 ± 0.83 | abcde | 2.59 ± 0.88 | ab | 4.89 ± 0.74 | bcdefghi | 0.63 ± 0.35 | d |
| Nine Pin Signature | 0.29 ± 0.21 | de | 2.02 ± 0.76 | ab | 4.68 ± 0.79 | cdefghij | 1.74 ± 0.55 | abcd |
| Orchard Hill 2019 Northern Spy | 4.25 ± 1.07 | ab | 2.34 ± 0.82 | ab | 7.08 ± 0.94 | abcd | 0.38 ± 0.19 | d |
| Original Sin McIntosh | 2.76 ± 0.94 | abcde | 1.98 ± 0.61 | ab | 5.13 ± 0.94 | abcdefgh | 2.59 ± 0.78 | abcd |
| Pennings Farm Cold Crash | 1.21 ± 0.6 | bcde | 2.02 ± 0.75 | ab | 4.62 ± 0.91 | cdefghij | 1.25 ± 0.6 | abcd |
| Potter's Dabinett | 2.06 ± 1.07 | abcde | 1.34 ± 0.55 | ab | 2.86 ± 0.59 | fghij | 1.03 ± 0.39 | abcd |
| Potter's Harrison | 3.44 ± 1.07 | abcd | 2.98 ± 0.94 | ab | 5.27 ± 0.83 | abcdefgh | 0.39 ± 0.25 | d |
| Potter's Hewe's Cuvee | 1.58 ± 0.66 | abcde | 2.12 ± 0.59 | ab | 5.02 ± 0.94 | abcdefghi | 2.38 ± 0.69 | abcd |
| Redbyrd 2020 Workman's Dry | 2.24 ± 0.91 | abcde | 1.41 ± 0.6 | ab | 5.56 ± 0.87 | abcdefgh | 1.08 ± 0.61 | abcd |
| Rootstock 2020 Heritage | 0.74 ± 0.44 | cde | 1.04 ± 0.52 | ab | 4.23 ± 0.72 | defghij | 1.44 ± 0.63 | abcd |
| Rose Hill SV3 Ellis Bitter | 2.9 ± 1.03 | abcde | 3.59 ± 1.05 | a | 5.86 ± 0.95 | abcdefg | 0.95 ± 0.51 | abcd |
| Shacksbury Deer Snacks IV | 0.78 ± 0.44 | cde | 2.21 ± 0.82 | ab | 4.94 ± 0.85 | bcdefghi | 0.83 ± 0.45 | abcd |
| Shelburne Iapetus | 1.76 ± 0.74 | abcde | 2.14 ± 0.77 | ab | 6.83 ± 0.94 | abcd | 0.66 ± 0.29 | d |
| SILO Hard Cider | 1.76 ± 0.74 | abcde | 1.59 ± 0.6 | ab | 4.16 ± 0.74 | defghij | 0.86 ± 0.39 | abcd |
| South Hill Baldwin | 0.99 ± 0.43 | bcde | 1.38 ± 0.62 | ab | 7.75 ± 1.05 | abc | 1.11 ± 0.45 | abcd |
| Stowe High and Dry | 2.12 ± 0.91 | abcde | 0.76 ± 0.49 | ab | 5.25 ± 1 | abcdefgh | 0.79 ± 0.38 | bcd |
| Tin Hat Fipenny Bit | 1.77 ± 0.73 | abcde | 1.45 ± 0.59 | ab | 2.21 ± 0.5 | hij | 1.09 ± 0.4 | abcd |
| Tumbling Creek Ridgerunner | 1.09 ± 0.55 | bcde | 2.44 ± 0.86 | ab | 7 ± 0.83 | abcd | 1.25 ± 0.47 | abcd |
| Westwind 2019 NATIVO | 1.59 ± 0.74 | abcde | 1.71 ± 0.71 | ab | 5.97 ± 0.93 | abcdef | 1.31 ± 0.56 | abcd |
| Winchester Malice | 1.25 ± 0.51 | bcde | 1.85 ± 0.86 | ab | 8.39 ± 0.7 | a | 1.79 ± 0.75 | abcd |
| Windfall Orchard Farmhouse | 0.83 ± 0.52 | cde | 1.49 ± 0.83 | ab | 5.64 ± 1.16 | abcdefg | 0.52 ± 0.31 | d |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Woodchuck Amber | 1.1 ± 0.61 | bcde | 1.75 ± 0.63 | ab | 2.83 ± 0.67 | fghij | 3.42 ± 0.92 | abc |

| | Lingering | | Moldy | | Oaky/Barrel | | Pear | |
|---|---|---|---|---|---|---|---|---|
| **Sample** | **Mean ± SE** | **Group** | **Mean ± SE** | **Group** | **Mean ± SE** | **Group** | **Mean ± SE** | **Group** |
| Abandoned Gold Rush | 5.34 ± 0.87 | abcd | 2.07 ± 0.92 | abcd | 3.11 ± 0.78 | ab | 0.53 ± 0.32 | c |
| Albemarle Black Twig | 5.88 ± 0.97 | abc | 1.8 ± 0.54 | abcd | 2.08 ± 0.68 | ab | 1.19 ± 0.56 | c |
| Albemarle Royal Pippin | 5.89 ± 0.81 | abc | 2.44 ± 1 | abcd | 2.48 ± 0.9 | ab | 0.75 ± 0.45 | c |
| Angry Orchard Crisp Apple | 2.93 ± 0.74 | cd | 0.78 ± 0.47 | abcd | 0.95 ± 0.48 | b | 1.81 ± 0.58 | abc |
| Bellwether Liberty Spy | 3.66 ± 0.72 | abcd | 1.56 ± 0.9 | abcd | 1.49 ± 0.61 | ab | 1.59 ± 0.6 | abc |
| Big Fish Wild Meadow | 4.11 ± 0.67 | abcd | 0.8 ± 0.46 | abcd | 1.61 ± 0.73 | ab | 1.1 ± 0.42 | c |
| Blue Bee Charred Ordinary | 6.41 ± 1 | a | 1.87 ± 0.88 | abcd | 1.04 ± 0.46 | ab | 1.25 ± 0.64 | c |
| Blue Bee Yarlington Mill | 5.82 ± 0.87 | abc | 1.82 ± 0.89 | abcd | 3.3 ± 0.84 | ab | 2.67 ± 0.61 | abc |
| Blue Toad Blue Ridge Blond | 2.92 ± 0.84 | cd | 0.38 ± 0.29 | bcd | 1.92 ± 0.8 | ab | 1.67 ± 0.65 | abc |
| Bold Rock Premium Dry | 3.52 ± 0.75 | abcd | 0.06 ± 0.04 | d | 0.83 ± 0.45 | b | 2.07 ± 0.7 | abc |
| Brooklyn Half Sour | 3.86 ± 0.93 | abcd | 0.43 ± 0.3 | bcd | 2.85 ± 0.87 | ab | 1.88 ± 0.71 | abc |
| Buskey RVA | 4.12 ± 0.88 | abcd | 1.04 ± 0.54 | abcd | 1.16 ± 0.48 | ab | 2.71 ± 0.78 | abc |
| Champlain Crimson Topaz | 3.85 ± 0.73 | abcd | 0.52 ± 0.33 | bcd | 1.81 ± 0.78 | ab | 1.99 ± 0.96 | abc |
| Citizen Unified Press | 3.37 ± 0.67 | abcd | 2.31 ± 1.05 | abcd | 0.71 ± 0.51 | b | 4.21 ± 1.06 | ab |
| Courthouse Creek 2019 Revival | 6.44 ± 0.82 | a | 3.23 ± 1.03 | abc | 4.39 ± 0.84 | a | 0.92 ± 0.49 | c |
| Eden Arborealis | 5.24 ± 0.87 | abcd | 1.55 ± 0.71 | abcd | 0.19 ± 0.14 | b | 1.25 ± 0.51 | c |
| Embark 2018 Reserve | 4.62 ± 0.82 | abcd | 2.56 ± 1.02 | abcd | 2.41 ± 0.86 | ab | 1.16 ± 0.48 | c |
| Eve's 2020 Albee Hill | 2.89 ± 0.71 | cd | 0.07 ± 0.04 | d | 2.53 ± 0.86 | ab | 1.54 ± 0.58 | bc |
| Fable Farm 2019 Emanation | 5.88 ± 0.8 | abc | 0.86 ± 0.58 | abcd | 3.31 ± 1.01 | ab | 1.12 ± 0.56 | c |
| Flag Hill Farm | 5.92 ± 0.71 | abc | 1.31 ± 0.53 | abcd | 3.13 ± 0.97 | ab | 0.81 ± 0.44 | c |
| New York Cider Co. Scrappy Dog | 5.25 ± 0.97 | abcd | 1.39 ± 0.69 | abcd | 2.51 ± 0.9 | ab | 1.75 ± 0.65 | abc |
| Nine Pin Signature | 3.66 ± 0.76 | abcd | 2.14 ± 0.85 | abcd | 2.04 ± 0.76 | ab | 1.84 ± 0.53 | abc |
| Orchard Hill 2019 Northern Spy | 4.71 ± 0.88 | abcd | 2.08 ± 0.77 | abcd | 2.44 ± 0.61 | ab | 1.2 ± 0.53 | c |
| Original Sin McIntosh | 4.44 ± 0.73 | abcd | 1.29 ± 0.56 | abcd | 0.93 ± 0.53 | b | 1.31 ± 0.48 | c |
| Pennings Farm Cold Crash | 2.63 ± 0.76 | d | 1.2 ± 0.57 | abcd | 2.12 ± 0.7 | ab | 4.32 ± 0.79 | a |
| Potter's Dabinett | 5.4 ± 0.74 | abcd | 1.15 ± 0.71 | abcd | 2.32 ± 0.99 | ab | 1.81 ± 0.56 | abc |
| Potter's Harrison | 3.66 ± 0.72 | abcd | 3.72 ± 1.25 | a | 1.4 ± 0.62 | ab | 1.27 ± 0.51 | c |
| Potter's Hewe's Cuvee | 4.11 ± 0.85 | abcd | 0.22 ± 0.17 | cd | 1.27 ± 0.62 | ab | 1.1 ± 0.45 | c |
| Redbyrd 2020 Workman's Dry | 4.04 ± 0.64 | abcd | 2.27 ± 0.94 | abcd | 1 ± 0.46 | ab | 0.43 ± 0.3 | c |
| Rootstock 2020 Heritage | 3.7 ± 0.8 | abcd | 0.45 ± 0.25 | bcd | 2.33 ± 0.85 | ab | 1.66 ± 0.55 | abc |
| Rose Hill SV3 Ellis Bitter | 5.38 ± 0.86 | abcd | 2.41 ± 1.07 | abcd | 2.74 ± 0.79 | ab | 0.59 ± 0.32 | c |
| Shacksbury Deer Snacks IV | 3.99 ± 0.69 | abcd | 0.43 ± 0.32 | bcd | 0.63 ± 0.36 | b | 0.86 ± 0.38 | c |
| Shelburne Iapetus | 3.49 ± 0.75 | abcd | 1.42 ± 0.71 | abcd | 2.09 ± 0.67 | ab | 1.88 ± 0.89 | abc |
| SILO Hard Cider | 2.99 ± 0.66 | bcd | 3.28 ± 1.29 | ab | 1.19 ± 0.6 | ab | 1.81 ± 0.6 | abc |
| South Hill Baldwin | 4.32 ± 0.85 | abcd | 0.56 ± 0.37 | bcd | 1.96 ± 0.67 | ab | 0.75 ± 0.38 | c |
| Stowe High and Dry | 4.65 ± 0.84 | abcd | 0.18 ± 0.17 | d | 1.16 ± 0.42 | ab | 1.61 ± 0.6 | abc |
| Tin Hat Fipenny Bit | 4.04 ± 0.79 | abcd | 1.24 ± 0.7 | abcd | 1.62 ± 0.74 | ab | 1.81 ± 0.68 | abc |
| Tumbling Creek Ridgerunner | 4.38 ± 0.79 | abcd | 0.04 ± 0.03 | d | 1.23 ± 0.48 | ab | 2.02 ± 0.58 | abc |
| Westwind 2019 NATIVO | 6.03 ± 0.95 | ab | 1.29 ± 0.75 | abcd | 1.59 ± 0.68 | ab | 1.35 ± 0.49 | c |
| Winchester Malice | 4.56 ± 0.99 | abcd | 1.42 ± 0.58 | abcd | 2.12 ± 0.81 | ab | 1.14 ± 0.51 | c |
| Windfall Orchard Farmhouse | 5.11 ± 0.74 | abcd | 0.57 ± 0.38 | bcd | 2.12 ± 0.92 | ab | 1.44 ± 0.61 | c |
| Woodchuck Amber | 3.37 ± 0.72 | abcd | 0.37 ± 0.36 | bcd | 1.28 ± 0.51 | ab | 1.74 ± 0.62 | abc |

| | Puckering | | Rotten Eggs (sulfuric) | | Smokey | | Solvent | |
|---|---|---|---|---|---|---|---|---|
| **Sample** | **Mean ± SE** | **Group** | **Mean ± SE** | **Group** | **Mean ± SE** | **Group** | **Mean ± SE** | **Group** |
| Abandoned Gold Rush | 5.54 ± 1.25 | abcdef | 1.49 ± 0.84 | bc | 0.42 ± 0.33 | c | 4.65 ± 1.18 | ab |
| Albemarle Black Twig | 6 ± 1.21 | abcde | 2.66 ± 0.74 | abc | 0.96 ± 0.6 | abc | 4.84 ± 1.4 | ab |
| Albemarle Royal Pippin | 3.8 ± 1.02 | bcdefghijkl | 1.7 ± 0.73 | abc | 1.12 ± 0.68 | abc | 3.95 ± 0.99 | ab |
| Angry Orchard Crisp Apple | 0.68 ± 0.34 | jkl | 2.06 ± 0.97 | abc | 0.08 ± 0.05 | c | 1.83 ± 0.74 | ab |
| Bellwether Liberty Spy | 1.36 ± 0.81 | ghijkl | 1.11 ± 0.47 | c | 0.16 ± 0.11 | c | 1.42 ± 0.67 | b |
| Big Fish Wild Meadow | 3.81 ± 0.88 | bcdefghijkl | 0.33 ± 0.28 | c | 0.71 ± 0.43 | bc | 2.67 ± 0.95 | ab |
| Blue Bee Charred Ordinary | 9.38 ± 0.94 | a | 0.71 ± 0.46 | c | 0.58 ± 0.35 | c | 2.89 ± 1.04 | ab |
| Blue Bee Yarlington Mill | 4.22 ± 1.33 | bcdefghijk | 0.93 ± 0.46 | c | 0.77 ± 0.5 | bc | 3.21 ± 1.02 | ab |
| Blue Toad Blue Ridge Blond | 0.35 ± 0.16 | l | 0.9 ± 0.42 | c | 0.78 ± 0.64 | bc | 1.35 ± 0.49 | b |
| Bold Rock Premium Dry | 0.46 ± 0.22 | kl | 0.03 ± 0.02 | c | 0.67 ± 0.38 | c | 2.2 ± 0.81 | ab |
| Brooklyn Half Sour | 3.74 ± 0.99 | bcdefghijkl | 0.24 ± 0.19 | c | 0.82 ± 0.53 | abc | 2.59 ± 0.88 | ab |
| Buskey RVA | 2.14 ± 0.84 | fghijkl | 2.67 ± 0.98 | abc | 0.62 ± 0.41 | c | 3.33 ± 0.82 | ab |
| Champlain Crimson Topaz | 2.47 ± 0.9 | efghijkl | 0.23 ± 0.21 | c | 0.38 ± 0.32 | c | 2.56 ± 1.11 | ab |
| Citizen Unified Press | 0.99 ± 0.56 | ijkl | 0.48 ± 0.35 | c | 0.37 ± 0.28 | c | 1.26 ± 0.6 | b |
| Courthouse Creek 2019 Revival | 6.49 ± 1.08 | abcd | 1.55 ± 0.63 | bc | 3.11 ± 1.04 | a | 4.03 ± 0.93 | ab |
| Eden Arborealis | 3.75 ± 1.09 | bcdefghijkl | 1.16 ± 0.9 | c | 0.75 ± 0.41 | bc | 3.61 ± 0.98 | ab |
| Embark 2018 Reserve | 2.69 ± 0.89 | defghijkl | 0.94 ± 0.64 | c | 0.42 ± 0.31 | c | 2.58 ± 0.98 | ab |
| Eve's 2020 Albee Hill | 3.16 ± 0.97 | cdefghijkl | 0.03 ± 0.02 | c | 0.27 ± 0.17 | c | 3.24 ± 1.08 | ab |
| Fable Farm 2019 Emanation | 7.25 ± 0.94 | ab | 0.01 ± 0.01 | c | 0.8 ± 0.56 | abc | 4.31 ± 1.15 | ab |
| Flag Hill Farm | 5.21 ± 1.1 | bcdef | 0.47 ± 0.38 | c | 1.34 ± 0.84 | abc | 3.58 ± 1.05 | ab |
| New York Cider Co. Scrappy Dog | 5.11 ± 1.13 | bcdefg | 1 ± 0.5 | c | 1.99 ± 0.76 | abc | 3.94 ± 1.05 | ab |
| Nine Pin Signature | 1.08 ± 0.54 | hijkl | 0.04 ± 0.02 | c | 0.48 ± 0.44 | c | 2.66 ± 0.88 | ab |
| Orchard Hill 2019 Northern Spy | 5.69 ± 1.15 | abcdef | 2.14 ± 1.02 | abc | 1.62 ± 0.55 | abc | 3.89 ± 1.13 | ab |
| Original Sin McIntosh | 2.08 ± 0.7 | fghijkl | 4.38 ± 1.16 | ab | 0.67 ± 0.35 | c | 3.13 ± 1.05 | ab |
| Pennings Farm Cold Crash | 0.9 ± 0.39 | ijkl | 0.89 ± 0.52 | c | 0.31 ± 0.27 | c | 1.83 ± 0.72 | ab |
| Potter's Dabinett | 3.55 ± 1.31 | bcdefghijkl | 0.58 ± 0.33 | c | 1.06 ± 0.51 | abc | 2.84 ± 0.96 | ab |
| Potter's Harrison | 4.2 ± 0.85 | bcdefghijk | 1.14 ± 0.53 | c | 0.5 ± 0.34 | c | 3.38 ± 0.86 | ab |
| Potter's Hewe's Cuvee | 5.04 ± 1.22 | bcdefg | 2.35 ± 1.02 | abc | 1.18 ± 0.7 | abc | 3.38 ± 1.15 | ab |
| Redbyrd 2020 Workman's Dry | 4.53 ± 0.91 | bcdefghi | 0.49 ± 0.47 | c | 0.71 ± 0.46 | bc | 2.17 ± 0.62 | ab |
| Rootstock 2020 Heritage | 2.33 ± 0.9 | efghijkl | 0.95 ± 0.69 | c | 1.73 ± 0.68 | abc | 2.54 ± 0.83 | ab |
| Rose Hill SV3 Ellis Bitter | 5.84 ± 1.21 | abcdef | 1.32 ± 0.54 | c | 1.65 ± 0.62 | abc | 3.43 ± 0.95 | ab |
| Shacksbury Deer Snacks IV | 5.87 ± 0.93 | abcdef | 0.06 ± 0.04 | c | 0.06 ± 0.03 | c | 2.1 ± 0.72 | ab |
| Shelburne Iapetus | 5 ± 0.97 | bcdefg | 0.89 ± 0.56 | c | 1.43 ± 0.67 | abc | 4.42 ± 1.06 | ab |
| SILO Hard Cider | 2.05 ± 0.63 | fghijkl | 0.24 ± 0.18 | c | 0.54 ± 0.49 | c | 2.53 ± 0.79 | ab |
| South Hill Baldwin | 5.24 ± 1.07 | bcdef | 0.52 ± 0.45 | c | 0.81 ± 0.48 | abc | 3.16 ± 1.09 | ab |
| Stowe High and Dry | 4.41 ± 1 | bcdefghij | 2.57 ± 0.85 | abc | 0.12 ± 0.1 | c | 2.24 ± 0.79 | ab |
| Tin Hat Fipenny Bit | 6.76 ± 1.13 | abc | 0.61 ± 0.31 | c | 1.63 ± 0.7 | abc | 4.12 ± 0.93 | ab |
| Tumbling Creek Ridgerunner | 2.74 ± 0.89 | defghijkl | 0.31 ± 0.27 | c | 0.81 ± 0.53 | abc | 1.99 ± 0.78 | ab |
| Westwind 2019 NATIVO | 4.86 ± 1.26 | bcdefgh | 0.05 ± 0.03 | c | 1.59 ± 0.6 | abc | 5.56 ± 1.32 | a |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Winchester Malice | 3.28 ± 1.17 | cdefghijkl | 4.57 ± 1.12 | a | 3 ± 1.03 | ab | 1.76 ± 0.62 | ab |
| Windfall Orchard Farmhouse | 3.09 ± 0.93 | cdefghijkl | 0.07 ± 0.05 | c | 0.65 ± 0.42 | c | 2.33 ± 0.87 | ab |
| Woodchuck Amber | 0.19 ± 0.11 | l | 0.95 ± 0.6 | c | 0.37 ± 0.22 | c | 1.08 ± 0.45 | b |

| | Sour | | Sweet | | Thick | | Vinegary | | Yeasty | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Sample** | **Mean ± SE** | **Group** | **Mean ± SE** | **Group** | **Mean ± SE** | **Group** | **Mean ± SE** | **Group** | **Mean ± SE** | **Group** |
| Abandoned Gold Rush | 5.84 ± 1.05 | bcdefghi | 1.39 ± 0.44 | lm | 3.8 ± 0.9 | abc | 4.32 ± 0.97 | abcd | 1.25 ± 0.51 | ab |
| Albemarle Black Twig | 5.95 ± 0.98 | bcdefghi | 1.72 ± 0.49 | klm | 5.03 ± 0.94 | abc | 3.44 ± 0.95 | abcdefgh | 1.25 ± 0.56 | ab |
| Albemarle Royal Pippin | 6.16 ± 1.05 | bcdefgh | 2.96 ± 0.6 | hijklm | 3.73 ± 0.99 | abc | 2.72 ± 1 | bcdefghi | 1.07 ± 0.49 | ab |
| Angry Orchard Crisp Apple | 1.2 ± 0.37 | m | 9.54 ± 0.79 | a | 6.18 ± 0.7 | a | 0.23 ± 0.11 | i | 2.77 ± 1.02 | a |
| Bellwether Liberty Spy | 1.93 ± 0.61 | klm | 8.49 ± 0.66 | abc | 5.59 ± 0.69 | ab | 0.62 ± 0.26 | ghi | 0.67 ± 0.37 | b |
| Big Fish Wild Meadow | 5.73 ± 0.93 | bcdefghi | 3.34 ± 0.71 | hijklm | 4.38 ± 0.83 | abc | 1.98 ± 0.7 | cdefghi | 0.88 ± 0.4 | ab |
| Blue Bee Charred Ordinary | 10.14 ± 0.7 | a | 1.03 ± 0.35 | m | 3.25 ± 0.94 | bc | 4.44 ± 0.85 | abcd | 0.78 ± 0.35 | b |
| Blue Bee Yarlington Mill | 3.1 ± 0.9 | ghijklm | 1.96 ± 0.6 | klm | 4.97 ± 0.93 | abc | 2.09 ± 0.74 | cdefghi | 1.21 ± 0.49 | ab |
| Blue Toad Blue Ridge Blond | 1.5 ± 0.49 | lm | 8.73 ± 0.89 | ab | 5.08 ± 0.94 | abc | 0.78 ± 0.31 | fghi | 1.39 ± 0.49 | ab |
| Bold Rock Premium Dry | 2.05 ± 0.79 | jklm | 8.21 ± 0.61 | abcd | 4.28 ± 0.66 | abc | 0.23 ± 0.15 | i | 0.48 ± 0.3 | b |
| Brooklyn Half Sour | 5.89 ± 1.05 | bcdefghi | 4.19 ± 0.8 | fghijkl | 4.03 ± 0.88 | abc | 3.96 ± 0.96 | abcde | 0.72 ± 0.39 | b |
| Buskey RVA | 2 ± 0.74 | klm | 5.74 ± 0.72 | cdefgh | 5.04 ± 0.52 | abc | 0.92 ± 0.56 | fghi | 0.5 ± 0.29 | b |
| Champlain Crimson Topaz | 3.91 ± 0.84 | efghijklm | 3.78 ± 0.83 | ghijklm | 3.38 ± 0.75 | bc | 1.89 ± 0.7 | cdefghi | 0.92 ± 0.43 | ab |
| Citizen Unified Press | 2.07 ± 0.79 | jklm | 8.86 ± 0.79 | ab | 4.49 ± 0.76 | abc | 0.52 ± 0.35 | hi | 0.48 ± 0.31 | b |
| Courthouse Creek 2019 Revival | 7.76 ± 0.81 | abcd | 1.73 ± 0.48 | klm | 4.32 ± 0.99 | abc | 5.69 ± 0.91 | a | 0.77 ± 0.43 | b |
| Eden Arborealis | 4.49 ± 0.77 | defghijklm | 2.29 ± 0.63 | jklm | 4.44 ± 0.74 | abc | 1.19 ± 0.47 | efghi | 0.39 ± 0.23 | b |
| Embark 2018 Reserve | 2.44 ± 0.67 | ijklm | 5.24 ± 0.71 | efghij | 3.9 ± 0.7 | abc | 0.86 ± 0.47 | fghi | 0.61 ± 0.33 | b |
| Eve's 2020 Albee Hill | 4.73 ± 1.04 | cdefghijklm | 3.33 ± 0.67 | hijklm | 2.67 ± 0.76 | c | 2.94 ± 0.84 | abcdefghi | 0.64 ± 0.37 | b |
| Fable Farm 2019 Emanation | 8.15 ± 0.93 | abc | 0.98 ± 0.38 | m | 3.98 ± 0.81 | abc | 3.97 ± 0.96 | abcde | 1.66 ± 0.59 | ab |
| Flag Hill Farm | 6.99 ± 0.94 | abcde | 4.4 ± 0.74 | efghijk | 4.19 ± 0.76 | abc | 2.76 ± 0.87 | abcdefghi | 1.57 ± 0.83 | ab |
| New York Cider Co. Scrappy Dog | 4.49 ± 0.84 | defghijklm | 2.13 ± 0.61 | klm | 3.88 ± 0.86 | abc | 3.56 ± 0.98 | abcdef | 1.18 ± 0.53 | ab |
| Nine Pin Signature | 2.69 ± 0.75 | hijklm | 7.19 ± 0.49 | abcde | 4.34 ± 0.64 | abc | 0.39 ± 0.26 | i | 0.54 ± 0.3 | b |
| Orchard Hill 2019 Northern Spy | 5.08 ± 1.02 | bcdefghijkl | 1.82 ± 0.5 | klm | 3.27 ± 0.78 | bc | 4.48 ± 0.82 | abcd | 1.01 ± 0.46 | ab |
| Original Sin McIntosh | 3.98 ± 0.71 | efghijklm | 6.76 ± 0.7 | abcdef | 5.74 ± 0.76 | ab | 0.63 ± 0.31 | fghi | 0.75 ± 0.37 | b |
| Pennings Farm Cold Crash | 2.49 ± 0.63 | ijklm | 6.48 ± 0.71 | bcdefg | 4.59 ± 0.76 | abc | 0.91 ± 0.48 | fghi | 0.68 ± 0.4 | b |
| Potter's Dabinett | 2.36 ± 0.69 | ijklm | 2.66 ± 0.63 | ijklm | 4.74 ± 0.74 | abc | 1.82 ± 0.62 | defghi | 1.18 ± 0.53 | ab |
| Potter's Harrison | 4.35 ± 0.82 | defghijklm | 2.99 ± 0.56 | hijklm | 3.64 ± 0.8 | abc | 3.91 ± 0.85 | abcde | 0.53 ± 0.34 | b |
| Potter's Hewe's Cuvee | 6.45 ± 0.91 | bcdefg | 5.34 ± 0.67 | defghi | 5.08 ± 0.96 | abc | 2.39 ± 0.89 | cdefghi | 1.23 ± 0.51 | ab |
| Redbyrd 2020 Workman's Dry | 5.5 ± 0.76 | bcdefghijk | 3.04 ± 0.63 | hijklm | 3.91 ± 0.74 | abc | 1.97 ± 0.54 | cdefghi | 1.01 ± 0.44 | ab |
| Rootstock 2020 Heritage | 3.07 ± 0.79 | ghijklm | 6.56 ± 0.83 | bcdefg | 4.08 ± 0.67 | abc | 1.38 ± 0.71 | efghi | 0.54 ± 0.33 | b |
| Rose Hill SV3 Ellis Bitter | 7.28 ± 0.99 | abcde | 1.53 ± 0.46 | klm | 3.47 ± 0.86 | abc | 5.64 ± 1.03 | ab | 0.79 ± 0.46 | b |
| Shacksbury Deer Snacks IV | 8.41 ± 0.75 | ab | 1.97 ± 0.54 | klm | 2.71 ± 0.8 | c | 3.49 ± 0.64 | abcdefg | 0.74 ± 0.3 | b |
| Shelburne Iapetus | 6.7 ± 0.98 | abcdef | 3.18 ± 0.56 | hijklm | 3.29 ± 0.68 | bc | 4.76 ± 0.86 | abc | 0.6 ± 0.29 | b |
| SILO Hard Cider | 3.34 ± 0.8 | fghijklm | 4.15 ± 0.64 | fghijkl | 3.38 ± 0.8 | bc | 0.69 ± 0.29 | fghi | 1.26 ± 0.68 | ab |
| South Hill Baldwin | 7.72 ± 0.78 | abcd | 1.76 ± 0.47 | klm | 3.71 ± 0.84 | abc | 2.82 ± 0.75 | abcdefghi | 0.51 ± 0.3 | b |
| Stowe High and Dry | 5.62 ± 0.79 | bcdefghij | 1.62 ± 0.5 | klm | 2.48 ± 0.74 | c | 2.26 ± 0.75 | cdefghi | 0.91 ± 0.43 | ab |
| Tin Hat Fipenny Bit | 8.65 ± 0.88 | ab | 1.11 ± 0.35 | m | 3.22 ± 0.93 | bc | 4.44 ± 1.03 | abcd | 0.6 ± 0.29 | b |
| Tumbling Creek Ridgerunner | 4.38 ± 0.9 | defghijklm | 2.6 ± 0.69 | ijklm | 3.26 ± 0.99 | bc | 1.32 ± 0.64 | efghi | 0.66 ± 0.42 | b |
| Westwind 2019 NATIVO | 4.51 ± 0.91 | defghijklm | 3.32 ± 0.78 | hijklm | 4.68 ± 0.97 | abc | 1.81 ± 0.65 | defghi | 0.4 ± 0.26 | b |
| Winchester Malice | 5.92 ± 1.09 | bcdefghi | 4.46 ± 0.78 | efghijk | 4.31 ± 0.9 | abc | 2.14 ± 0.96 | cdefghi | 1.77 ± 0.65 | ab |
| Windfall Orchard Farmhouse | 5.19 ± 0.85 | bcdefghijk | 2.36 ± 0.5 | jklm | 2.62 ± 0.7 | c | 1.66 ± 0.58 | defghi | 0.44 ± 0.26 | b |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Woodchuck Amber | 1.5 ± 0.49 | lm | 9.54 ± 0.65 | a | 5.5 ± 0.75 | ab | 0.17 ± 0.13 | i | 0.19 ± 0.15 | b |

## Supplementary Material II

Sample Evaluation Order

| | |
|---|---|
| 1 | Woodchuck Amber |
| 42 | Angry Orchard Crisp Apple |
| 2 | Fable Farm 2019 Emanation |
| 41 | Abandoned Gold Rush |
| 3 | Flag Hill Farm |
| 40 | Original Sin McIntosh |
| 4 | Stowe High and Dry |
| 39 | Embark 2018 Reserve |
| 5 | Windfall Orchard Farmhouse |
| 38 | Orchard Hill 2019 Northern Spy |
| 6 | Citizen Unified Press |
| 37 | South Hill Baldwin |
| 7 | Tin Hat Fipenny Bit |
| 36 | Rose Hill SV3 Ellis Bitter |
| 8 | Shacksbury Deer Snacks IV |
| 35 | Westwind 2019 NATIVO |
| 9 | Eden Arborealis |
| 34 | Redbyrd 2020 Workman's Dry |
| 10 | SILO Hard Cider |
| 33 | Bellwether Liberty Spy |
| 11 | Champlain Crimson Topaz |
| 32 | Eve's 2020 Albee Hill |
| 12 | Shelburne Iapetus |
| 31 | Nine Pin Signature |
| 13 | Buskey RVA |
| 30 | Rootstock 2020 Heritage |
| 14 | Bold Rock Premium Dry |
| 29 | Brooklyn Half Sour |
| 15 | Blue Bee Charred Ordinary |
| 28 | New York Cider Co. Scrappy Dog |
| 16 | Winchester Malice |
| 27 | Pennings Farm Cold Crash |
| 17 | Big Fish Wild Meadow |
| 26 | Courthouse Creek 2019 Revival |
| 18 | Blue Toad Blue Ridge Blond |

| | |
|---|---|
| 25 | Blue Bee Yarlington Mill |
| 19 | Tumbling Creek Ridgerunner |
| 24 | Potter's Harrison |
| 20 | Albemarle Royal Pippin |
| 23 | Potter's Dabinett |
| 21 | Albemarle Black Twig |
| 22 | Potter's Hewe's Cuvee |
| 2 | Fable Farm 2019 Emanation |
| 1 | Woodchuck Amber |
| 3 | Flag Hill Farm |
| 42 | Angry Orchard Crisp Apple |
| 4 | Stowe High and Dry |
| 41 | Abandoned Gold Rush |
| 5 | Windfall Orchard Farmhouse |
| 40 | Original Sin McIntosh |
| 6 | Citizen Unified Press |
| 39 | Embark 2018 Reserve |
| 7 | Tin Hat Fipenny Bit |
| 38 | Orchard Hill 2019 Northern Spy |
| 8 | Shacksbury Deer Snacks IV |
| 37 | South Hill Baldwin |
| 9 | Eden Arborealis |
| 36 | Rose Hill SV3 Ellis Bitter |
| 10 | SILO Hard Cider |
| 35 | Westwind 2019 NATIVO |
| 11 | Champlain Crimson Topaz |
| 34 | Redbyrd 2020 Workman's Dry |
| 12 | Shelburne Iapetus |
| 33 | Bellwether Liberty Spy |
| 13 | Buskey RVA |
| 32 | Eve's 2020 Albee Hill |
| 14 | Bold Rock Premium Dry |
| 31 | Nine Pin Signature |
| 15 | Blue Bee Charred Ordinary |
| 30 | Rootstock 2020 Heritage |
| 16 | Winchester Malice |
| 29 | Brooklyn Half Sour |
| 17 | Big Fish Wild Meadow |

| | |
|---|---|
| 28 | New York Cider Co. Scrappy Dog |
| 18 | Blue Toad Blue Ridge Blond |
| 27 | Pennings Farm Cold Crash |
| 19 | Tumbling Creek Ridgerunner |
| 26 | Courthouse Creek 2019 Revival |
| 20 | Albemarle Royal Pippin |
| 25 | Blue Bee Yarlington Mill |
| 21 | Albemarle Black Twig |
| 24 | Potter's Harrison |
| 22 | Potter's Hewe's Cuvee |
| 23 | Potter's Dabinett |

# Chapter 4 – Appeal of the Apple: Exploring consumer perceptions of American cider in the Northeast and Mid-Atlantic United States


## *Abstract*

Alcoholic or “hard” cider is experiencing a resurgence in popularity, particularly throughout the Northeast and Mid-Atlantic regions of the United States. Yet, the American cider industry is also marked by knowledge gaps among consumers and industry stakeholders regarding cider integrity, quality, and styles. What defines and distinguishes cider amongst the sea of options in the saturated alcoholic beverage market? This study aimed to explore the consumer preferences of American hard cider using a phenomenological, qualitative approach. The research comprised 14 semi-structured, contextual focus groups with regular cider consumers (99 participants) throughout three leading cider producing states in the Northeast and Mid-Atlantic United States: Virginia, Vermont, and New York. All focus group sessions were subject to inductive thematic analysis for themes broadly related to cider product preference and the cider-drinking experience. Results of the study suggest that cider preference is motivated largely by sensory quality, but that various other factors also influence the cider drinking experience including perceived health effects, regionality and proximity, the drinking occasion, and product information. Results also emphasize the importance of localness, community, and nostalgia in cider sensory experiences, as well as the role of social and cultural norms in consumer valuation of cider products. Overall, the research highlights diverse preferences for cider among consumers, which will have broad implications for the cider industry relative to marketing, economics, product development, and sensory science. As well, this research serves as a template for using qualitative research methods to better understand consumer preferences in the food and beverage industries.



## *Keywords*

Cider; consumer; sensory; community; flavor


## *Publication Note*

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## *Introduction*

Cider, also known as hard cider in the United States, is an increasingly popular beverage worldwide (Bundele & Deshmukh, 2022). In the United States (US) specifically, the

cider industry is seeing a renewed public appeal, growing an average of 6.1% per year in recent years (Fabien-Ouellet & Conner, 2018; Jacobsen, 2020, 2021; Kline & Cole, 2017; Lombardo, 2022). However, consumer preferences have also begun to shift towards regional brands that produce much smaller volumes of cider compared to the larger brands that led the United States' cider resurgence in recent decades (Wood, 2022). Though the cider industry is expected to grow over the next five years, cider producers and retailers still lack a clear understanding of the factors which drive someone to become a cider consumer and that contribute to the repeat purchasing of cider products (Yenerall et al., 2022; Fabien-Ouellet & Connor, 2018).

Apples and cider have a rich American history beginning with North American indigenous communities who grew crabapples (Abrams & Nowacki, 2008; Kerrigan, 2008), followed by early European settlers who began organized orcharding and cider-making. During colonial times, different apples from different regions were well-believed to yield ciders of different quality and flavor, cider and apples were a valuable export crop up, and it is estimated that by the 1800's almost every home in New England sustained an apple orchard (A. F. Smith, 2014). Today, New York, Virginia, and Vermont rank 1st, 8th, 12th respectively as US states with the most cideries (West, 2018) alongside a rich apple-growing and cider-making heritage. In particular, regions such as the Lake Champlain Watershed (Vermont), Hudson Valley (New York), the Finger Lakes (New York), and the Shenandoah Valley (Virginia) have supported active orchards and cider making cultures for over two centuries (Calhoun, Jr., 2010; Guttmann, 2012; Kline & Cole, 2017; M. Smith & Lal, 2017).

To date, research into cider quality has focused heavily on the chemical composition of apples and cider (Antón et al., 2014; del Campo et al., 2006; Le Quéré et al., 2006; Ma, Neilson, Lahne, Peck, O'Keefe, & Stewart, 2018; Ma, Neilson, Lahne, Peck, O'Keefe, Hurley, et al., 2018; Rosend et al., 2019), cider production and processing methods (Alexander et al., 2018; Boudreau, Peck, Ma, et al., 2017; Boudreau, Peck, O'Keefe, et al., 2017; Calugar et al., 2021; Hang & Woodams, 2010), fermentation quality and techniques (Morrissey et al., 2004; Nogueira et al., 2008; Rosend et al., 2020; Sánchez et al., 2014), willingness to pay for cider products (Didier et al., 2012; Fur & Outreville, 2022; Jensen et al., 2021; M. Smith et al., 2021; Tozer et al., 2015), and sensory profiling of ciders made according to different techniques and from specific regions (Cole et al., 2022; Kessinger et al., 2020; Littleson et al., 2022; Phetxumphou et al., 2020). Cider produced domestically can be made according to varying methods, produced over varying amounts of time (which can range from a few weeks to many months), and from many different types (i.e., varieties or cultivars) of apples. Cider apples have been traditionally prescribed for cider-making in contrast to apples intended for baking or fresh eating because they provide bitterness, tartness, and other flavors which contribute complexity and body to a cider beverage (Alexander & Ewing Valliere, 2020; Merwin et al., 2007; Soomro et al., 2022; Thornton, 2014). Apples have been compared to grapes used for wine-making: their composition is impacted by geography, orchard practices, seasonal climate, and more (Brennan, 2019; Ma, Neilson, Lahne, Peck, O'Keefe, & Stewart, 2018; Ma, Neilson, Lahne, Peck, O'Keefe, Hurley, et al., 2018; Proulx & Nichols, 1980).

The aforementioned research on American cider chemistry, sensory quality, consumer behavior, and consumer valuation are critical for understanding cider quality. However, the ways in which broader sociocultural, agricultural, and historical factors influence consumers' definitions of quality in the whole American cider drinking experience still remain unclear. With

food and beverage products, sensory and consumer research is useful for identifying environmental and social factors – also known as context – which can affect consumption experiences. Consumer research is critical for the success of new products because it empowers producers to create products that satisfy consumer desires (van Kleef et al., 2005). For this reason, vast amounts of research focus on consumers' preferences and their product experiences, considering the effects of context, to explore how and why consumers place value on different products (Betancur et al., 2020; Bruwer et al., 2011; Calvo-Porral & Levy-Mangin, 2019; Charters & Pettigrew, 2007; Desmet & Hekkert, 2007; Schifferstein, 2009; Spence, 2020; Spence & Wang, 2017; Yang & Lee, 2021).

Because food and beverage preferences are deeply contextual and experiential (Betancur et al., 2020; Cotter et al., 2022; Galiñanes Plaza et al., 2022; Lahne et al., 2017; Meiselman, 2019; Nijman et al., 2019, 2022), qualitative research can be invaluable for better understanding consumer experiences and preferences. Specifically, within qualitative research, phenomenology aims to summarize common and shared preferences and perspectives, often utilizing focus groups (Creswell & Poth, 2018; Moustakas, 1994; van Manen, 1990) and reflexive thematic analysis to explore broad themes across what participants say (Braun & Clarke, 2006, 2013; Holton, 1973). Phenomenology within qualitative research considers how multiple "realities" can coexist among those with shared experiences (Braun & Clarke, 2013, p.6). These methods has been used on a variety of foods and beverage products to identify consumer affective responses, as well as what other factors influence purchasing habits, consumption patterns, and more (Barlagne et al., 2017; Cardinal et al., 2003; Chung et al., 2011; Gómez-Corona et al., 2016, 2017; Lahne & Trubek, 2014; North et al., 2021). To be specific, qualitative research methods have been invaluable in documenting the social and cognitive experiences that are possible with particular food and beverage products (Charters & Pettigrew, 2008; Gómez-Corona et al., 2017; Lahne & Trubek, 2014). In the food and beverage sector, qualitative research helps scientists to develop a holistic understanding of the sensory experience of food and beverage consumption.

The current research uses phenomenological research methods to explore consumer preferences of cider and their subjective, lived experiences of drinking cider in the Northeast and Mid-Atlantic US. This paper reports on the methodological framework and findings of focus group research conducted using an inductive approach and reflexive thematic analysis in order to take a snap-shot of consumer preferences for cider. The primary objective of this research is to develop a contextualized understanding of *what* consumers in the Northeast and Mid-Atlantic prefer and value about hard cider and *why*, without prescribing to any pre-established assumptions regarding these questions. Results of this research suggest that sensory quality, economic embeddedness, connectedness, and nostalgia drive consumer preferences for and perception of cider and cider-drinking experience. These findings further exemplify the use of qualitative research methods for exploring the multifaceted elements which affect food preference, valuation, and regional food-related identities.

## *Methods*

Focus group sessions were conducted in two phases: (1) focus groups throughout Virginia (April-June 2021), and (2) focus groups in Vermont and New York (July-August 2021). Sessions occurred over the span of six months in part to accommodate social gathering restraints due to the COVID-19 pandemic. Focus group participants were recruited through University and cidery listservs and social media sites, local grocery stores, and word-of-mouth in local communities. These recruitment methods were chosen in order to find cider drinkers from a diversity of backgrounds and livelihoods and are common for qualitative research (Krueger & Casey, 2015). Screening criteria for selection to participate in a cider focus group included: self-reporting as not currently pregnant and self-reporting as drinking cider at least one to two times per month. Consistent cider consumption was required for participation in our cider focus groups because research suggests that those with more product knowledge are more easily able to articulate their preferences (Bell & Marshall, 2003; Hopfer & Heymann, 2014; Jamir et al., 2020; Langlois et al., 2011).

All focus group sessions occurred in contextual settings (i.e., regular cider consumption settings) in order to (1) enhance the accessibility and regional diversity of settings where the research was conducted, (2) to foster more comfortable settings for participants to be honest about their experiences and preferences (Krueger & Casey, 2015), and (3) to stimulate discussion about cider-drinking environments and how that impacts people's cider-drinking experiences. In addition, scholars in sensory science research particularly emphasize the value of contextual, "real-life" research settings for improving the real-world validity of consumer preference testing and sensory science (Krueger & Casey, 2015; Meiselman, 2013; Meiselman et al., 2022; Stelick & Dando, 2018). All focus group sessions were audio-recorded and transcribed.

Focus group sessions followed a semi-structured questioning route (see *Supplementary Material I)* that asked questions related to favorite cider brands/producers, purchasing habits and motivation, expectations differentiating the beer/wine/cider-drinking experiences, packaging, and valued sensory qualities of cider. All participants were asked to complete a brief, voluntary demographic survey (including questions related to income, age, and gender identity) prior to their participation in a session.

Three (3) cider samples were provided during focus group sessions for participants to taste and discuss. For each session, all three ciders used for sampling were purchased locally and made in the respective state, so as to include ciders that were easily recognizable to participants. The three selected samples were chosen to cover a range of possible cider categories, including a modern-style commercial cider, a single varietal cider, and a third cider chosen on by the moderator based on local availability. All cider samples were first presented blind, then the label and packaging of each sample was revealed after discussion of that sample. Revealing the tasted product and discussing packaging, branding, and other product information following tasting was done to stimulate discussion related to product perception. Participants were encouraged to share their honest opinions about cider, the provided cider samples, and anything pertaining to the cider-drinking experience. This study was approved by the Virginia Tech Institutional Review Board (VT IRB # 20-880). All subjects gave their informed consent for participation.

### Data Analysis

After transcription, all data was analyzed using NVivo software (QSR International Pty Ltd., 2020) using reflexive thematic analysis (Braun and Clarke, 2006, 2013, 2019). Data analysis followed an inductive approach, intended to explore the data "as-is" and without a pre-established theory, in order to broadly explore the research question: "What do cider consumers like about hard cider and why?" In doing so, researchers intended to uncover ideas beyond explicit statements of preference. Our analysis considered and reflected on the influence of context on participant's responses.

Data analysis followed the phases of reflexive thematic analysis, outlined by Braun and Clarke (2006; 2013): the first author (MDC) conducted all focus group sessions, transcribed all audio-recordings, became familiarized with all data, and generated initial codes and initial themes, constituting the main analysis. The senior author (JL) read all transcriptions for familiarization and reviewed all relevant codes for consistency. Together, they discussed and agreed upon all generated codes, code descriptions, and supporting quotes across the sessions to identify, name, and review the final themes. Second, third, fourth, and fifth authors read and reviewed final themes and supplementary quotes for validity.

## *Results & Discussion*

In total, 99 participants (52 female; 39 male) participated in 14 focus groups (5 in Virginia, 3 in Vermont, 6 in New York). Results of the demographic survey completed by 91 participants are shown in *Table 2*. The number of participants per focus group ranged from 4 to 10, and sessions lasted between 50-75 minutes. Details for each focus group session are provided in *Table 1*. Six primary themes summarize answers that consumers presented to questions about their cider preference and the cider-drinking experience: *Perceived Health Effects*, *The Drinking Occasion*, *The Importance of Flavor*, *Cider-making Knowledge*, *Localness, Community, Nostalgia*, and *Paying for Cider*. The next section discusses these themes with supplementary quotes in order of apparent complexity: beginning with seemingly simple factors that initially attract consumers to cider and which guide their everyday sensory experiences, and proceeding into the more complex and diverse themes that influence these consumers' preferences. In this way, our discussion of the proposed themes intends to build a rich, thick story about the cider consumption experience, becoming more detailed and heavily contextualized as discussion on the cider experience unfolds.

We visually summarize these overarching themes in *Figure 1* and *Figure 2*. In *Figure 1*, we explore how consumers define "good cider" primarily in terms of flavor, the drinking occasion, product information, and price. This graphic intends to make our results actionable and easy to understand using a "choose-your-own-adventure" format. In *Figure 2*, we extend the concepts summarized in *Figure 1* by integrating underlying, latent observations of consumer perceptions and values.

### Perceived Health Effects

What attracts consumers to engage with the cider world to begin with? In the focus groups, many consumers were initially drawn to cider because they believed cider to cause less

intense alcohol-related physical effects and less intense digestive effects. Particularly, some consumers exclusively drank cider because of gluten intolerance: *"I started drinking ciders because I was diagnosed with Celiac, so I had to stop drinking beer."* (Group1_04). Consumers frequently reported feeling less full or bloated when drinking cider compared to beer, and they valued the perceived decreased sugar content of cider compared to wine: *"that's one of the reasons why I switched to cider I was a dry red wine drinker. And personally because the residual sugar in the wine was higher"* (Group4_05). Lastly, these consumers also spoke about how the intoxication side-effects of cider were less intense and debilitating: *"I even think, to speak a little crudely the buzz you get from cider is different… than a red wine or drinking bourbon"* (Group8_05). These findings add new evidence to the body of factors which drive consumer interest in cider products (M. Smith et al., 2021; Yenerall et al., 2022). Given that perceived health benefits and effects are relevant in the wine and beer industries (Chrysochou, 2014; Yoo et al., 2013), it may be relevant to further explore the perceived physical effects of cider in order to guide cider marketing related to such elements of the cider drinking experience.

## The Importance of Flavor

When consumers were asked what makes a good cider, what makes a cider their favorite, and what drew them to cider to begin with, the overall theme of flavor was brought up most frequently. In this section, we discuss the importance of flavor in driving consumers' sensory preferences as well as how consumer preferences related to sensory quality can be framed by sociological theories. We begin with a direct explanation of liked and disliked sensory attributes followed by a discussion about consumer interest in learning where specific sensory qualities originate from relevant to the cider production process. From here, we examine how reflecting upon the sensory experience, both when supplemented with extrinsic product information and when not, is a sign of *amateurship* (Hennion, 2007; Teil & Hennion, 2018) — a way of experiencing a product that is attentive, passionate, and reflexive, and opposed to pure consumption, which can be passive and reactive.

Sensory characteristics that came up frequently, such as sweetness, dryness, "complexity", "funk", carbonation, tartness, aroma, and aftertaste, all contributed to the "goodness" of a cider, as depicted in *Figure 1*. For many of the sensory characteristics that consumers described, opinions varied substantially: some consumers liked extreme flavors, though most consumers preferred a balance of any given sensory attribute. In addition, consumers tended to use sensory terms in ways that are substantially different from their accepted definitions by cidermakers, enologists, and other experts (see, for example, the use of "rancid" below), a phenomenon that has been noted extensively in previous publications (Kessinger et al. 2020).

For example, where one consumer preferred a *clean* flavor profile in cider, others preferred extreme "funkiness" and "rancidity": *"It's usually going to a bar… and asking for the most rancid wine or cider and that's probably the one I'll like"* (Group9_04). Relevant to dryness and sweetness, most consumers in the present study preferred "dry cider" or a subtle sweetness. Tozer et al. (2015) reported that increasing sweetness decreased consumers' willingness to pay for cider, while the report by Dawson et al. (2019) suggested consumers prefer both sweetness and acidity, specifically in a sample set of single varietal ciders made from cider-specific apples. Most consumers in the present study emphasized a desire for

"tartness" and "acidity," aligning in part with Dawson et al. (2019). Most cider consumers also preferred sparkling cider and were unaware that non-carbonated cider existed; however, one consumer passionately enjoyed "still" cider. These diverse consumer preferences are similar to findings reported by (Cole et al., 2022), who recently reported distinct clusters of cider consumers based on their different sensory preferences.

Interestingly, many consumers seemed to express ambivalence towards "apple-y-ness", where they wanted unique flavors to come from the apples, but they did not want an explicit, sweet, apple-like flavor: *"I don't like things that taste like apple juice… like a kid's drink and it's very apple forward but it's sweet apple and I would rather have like a tart apple or bitter apple"* (Group6_05)*; "I tend to go for ciders that have the straight classic just apple, on the dry side"* (Group12_02). Relatedly, consumers expressed distaste for sticky mouthfeels and related *excessive* sweetness: *"It's like stickiness… like if my mouth feels sticky after a sip. That's the opposite of sessionable"* (Group13_01). As another consistent pattern relevant to sensory quality, consumers disliked "eggy" or "sulfuric" aromas — *"It has a big sulfur smell to me, which is kind of off-putting"* (Group2_02) — as well as undefined bad aromas or aftertastes —*"It has an aftertaste, like waking up with like bad breath… that like is lingering"* (Group2_06).

The frequent mention of and consensus on "bad" flavors, such as "sulfuric" aromas, unidentifiable aromas and aftertastes, and excessive sweetness suggest that there is a need for trustworthy information on identification, causation, and remediation of common sensory faults to support improved cider quality. "Funkiness," often discussed in the context of specific faulted qualities in wine (e.g., "barnyard") and a characteristic feature of some European ciders (Alexander & Ewing Valliere, 2020; Maykish et al., 2021), was an attribute widely discussed by consumers to offer "complexity" and "depth" in cider. Divided opinions amongst consumers about how much and what kinds of "funkiness" they prefer suggests that intensities and types of "funkiness" may deserve a broader investigation in the context of cider (Colomer et al., 2020; Crauwels et al., 2015; Thompson Witrick et al., 2017). "Complexity" is also a term that has been used ambiguously in the wine industry (Wang & Spence, 2018, 2019), and so investigations into cider complexity may be warranted given the appeal of this dimension of quality to some consumers.

Consumers viewed the cider marketplace to have a diverse yet approachable range of sensory options among products, as well as easier-to-understand product information compared to the beer and wine marketplaces where consumers reported too large of a product space to "try them all" (e.g., beer) and too much product information (e.g., wine): *"there's a lot more variety in what people call a beer… like a whole thing of IPAs… you could never try them all in your whole life, that's just one part of the whole beer spectrum… I feel like I am more comfortable ordering a cider… because it's not as dangerous"* (Group2_08). Yet, consumers were also often surprised by the diverse, unique flavor experiences that they got within individual cider products, motivating them to explore and develop their own preferences within a new product space: *"I like how unique cider is… cider has a unique flavor and that really stands out and then you start to like personalize"* (Group5_04).

Lastly, a majority of consumers liked ciders that were flavored or co-fermented with non-apple ingredients such as seasonal adjuncts, fruits, herbs, botanicals, hops, ginger, or cocktail-emulating ingredients: *"I do enjoy trying ciders that have like seasonal fruits or herbs."* (Group11_04). Frequently mentioned and enjoyed flavorings were the use of ginger and fruits

such as berries, currants, pomegranate, and grapefruit. Flavored ciders were also cited as something that motivated consumers to explore new cider products.

### Introducing Amateurship

In contrast to preferences for flavored ciders, some consumers preferred ciders made only with apples. These consumers, representing roughly one quarter to one third of all consumers in the research, seemed to largely dislike flavored ciders because they thought other fruits can easily overpower the natural flavors from the apple: *"I don't like things that take away from the apple… for me cider should be made from apples and if there are other things… the story is lost"* (Group8_04). These consumers described how they simply liked *"traditional cider"* (Group4_10) because these types of ciders allowed consumers to engage with how cider production factors, specifically apple varieties and place, impact cider sensory quality: *"I like searching out the complexity… there's always something different, even batch to batch…they're using a lot of crab apples, they're sourcing a lot of wild yeast, it's always something a little bit different. And that's also why I got into ciders 'cause I don't want to drink the same thing over and over again"* (Group7_07); *"you know it's one apple and you can really taste the layers of flavor… in the area where it's coming from. So you know it… feels more localized in that way and you can taste the differences in certain fruits or in areas and I think that's really interesting."* (Group5_02).

The consumers who are explicitly, consciously interested in better understanding and refining their tastes with practice (i.e., continued consumption) and with supplemental information act as *amateurs* in Hennion's model of active and reflexive tasting (2007; see *Figure 2*). To these consumers, the sensory experience is an opportunity to learn, question, discover, share, and reflect on their consumption experiences (Hennion, 2007; Teil & Hennion, 2018). These observations are comparable to how product information can stimulate cognitive, reflective taste experiences in other "craft" sectors such as beer (Gómez-Corona et al., 2017), wine (Charters & Pettigrew, 2007, 2008), and artisan cheese (Lahne & Trubek, 2014). In particular, American cider offers the potential for many cognitive factors to enhance the sensory experience, such as cider production time, aging time, fermentation vessels or equipment, fermentation methods or microorganisms, apple varieties, apple-growing practices, apple-growing location(s), and the geographical origins of any other ingredients. However, not all consumers wanted the cider sensory experience to be reflective and thought-provoking – *"I like learning about it… am I going to put together a spreadsheet about what I like[?] I do that for certain things but I'm not doing it about this because I need it to be light, crisp, refreshing and not a THING"* (Group1_02) – an observation that fits Hennion's description of *non-amateurs* who choose to accept "a casual glass, thinking of other things" (Hennion, 2007, p. 108).

Regardless of whether these consumers seek an active, reflective sensory experience or not, almost all consumers discussed evolving preferences over the course of their cider-drinking: *"when I started [drinking cider], I just wanted something sweet, standard… other people are going out drinking. I want to drink something but I'm not into beer, so I just want something sweet to sip on. But then it started changing, and it's just all over the place… I could do sweet or dry"* (Group6_01). These observations highlight how the more one consumes something, the more one becomes sensitized to new sensations, different sensations, and the sensations that one prefers (Hennion, 2007; Teil & Hennion, 2018). *Amateurship,* in the context

of cider consumption, comes in different forms – one can decipher how their tastes have changed and decide to reflect upon the tasting experience, but one can also consciously choose to not do one or both of these things as well. Cider preference also embodies the spectrum of different levels of *amateurship* (Teil & Hennion, 2018), which likely also extend beyond cider consumption: the non-*amateur* is not engaged or concerned with their tasting at all, the young *amateur* has tastes that unconsciously evolve yet are not thoroughly understood, the *amateur* is deeply engaged with the process of tasting and how their perception changes with time and space – and all of these states of *amateurship* can fluctuate.

Beyond the sociological dimensions of active tasting and *amateurship*, the extensive discussion about how sensory quality primarily drives cider consumers' preferences and drinking experiences with American cider aligns with previous research. Kessinger et al. (2020) reported that expected sensory quality was a leading driver of purchase or consumption intent for cider products among Virginia consumers. Many other researchers have also reported that sensory quality is a key driver of consumer liking in alcoholic beverages overall (Bruwer et al., 2011; Gómez-Corona et al., 2017; Muggah & McSweeney, 2017; Thibodeau & Pickering, 2017). In cider, specifically, diverse preferences for flavor and flavor knowledge among consumers highlights the potential viability of a diversely flavored marketplace, as well as a critical need for educational resources and clear marketing of sensory-specific information oriented towards consumers.

## The Drinking Occasion

Closely related to cider sensory quality, consumers reported a range of occasions that were conducive to drinking cider, which we summarize into two contrasting categories: "casual" consumption occasions and "intimate" consumption occasions. We outline how these consumption occasions are relevant to the cider-drinking experience in *Figure 1,* showcasing their direct relation to elements of sustainability, packaging, ABV content, sensory quality, and food-pairing.

Casual consumption occasions include but are not limited to outdoor activities, summer-related activities, large social gatherings, or relaxing in general. During these types of consumption occasions, consumers preferred lighter, refreshing, and crisp flavor profiles, canned packaging, and generally cheaper prices – all of which went hand-in-hand. Canned cider was widely viewed as *"cheaper"* and more accessible: *"Cans are more approachable… borrowing from beer"* (Group8_04). However, cans were often associated with a worse aftertaste. In keeping with discussion of beer and wine alternatives, casual consumption occasions rendered cider-as-beer-replacement, as explained by Group3_02 in two instances: *"the Blue Bee cider to me… it's more like having a glass of wine, more delicate… more effervescent, whereas the ciders that I drink it's more like having a pint of beer"* and *"a Buskey RVA cider or an Angry Orchard has kind of the same sensation as drinking a beer, except I prefer the flavor, whereas the Blue Bee ciders are refined like wine."*

Intimate consumption occasions include but are not limited to small social gatherings, dinner and food-pairing, and celebratory occasions. On these types of occasions, consumers were more interested in complex, tannic, or "funky" flavor profiles, allowing ciders to contrast well with food (see *Figure 1* and *Figure 2*). These ciders also tended to be in bottled packaging, rendering intimate consumption occasions as a cider-as-wine-replacement. Bottled cider,

though associated with better sensory quality, was viewed as intimidating for some consumers and raised fears of product waste: *"A can is comfortable, it's a sizable amount that I can consume and I don't have to waste it"* (Group2_05); *"I have this thing with wine too where I'm intimidated to open the bottle because I don't want it to go to waste"* (Group10_03). Because of this, some consumers also expressed a desire for higher quality cider to be available in 12-ounce glass bottles.

Generally, consumers appeared to have their own internal script for the cider-drinking experience, occasion, and their purpose for drinking: they were either drinking for the intoxicating effects of a "pleasant-enough" beverage or to explicitly experience a product that is made with a different, intentional level of care. In the latter situation, consumers wanted and valued cider-making information, a critical piece of the reflexive taste experience (Hennion, 2007; Teil & Hennion, 2018): intentional tasting is best suited for certain occasions and a specific ambience. In this way, consumers with more advanced *amateur*-like tendencies will tend to more intimate drinking experiences in order to have that active, reflective experience. Further, consumers viewed the cider industry as one in which different types of products, different standards of quality, and different brands are best suited for different occasions and purposes (emphasized in *Figure 2*). But, they also viewed this division as an asset to the cider industry by making cider capable of simultaneously being a "low-" and "high-brow" product: *"[I]t depends on what purpose the cider is serving. So most of the time when I'm drinking cider, I'm thinking of it as a wine replacement. So in that scenario, I want it to be… more pure… more straightforward apple more about the process of being made. But also sometimes you're sitting in the hot sun and you want it as a beer replacement… I don't think it always has to be a highbrow item it can also be a low brow item"* (Group13_03).

## Cider-making Knowledge

This last aspect of *Drinking Occasion* – whether or not the occasion was conducive to learning cider-making information – is connected to the third major theme: *Cider-making Knowledge*. *Figure 1* highlights how intimate drinking occasions allow for the appreciation of more product information. Many consumers were simply interested in learning about how cider products were made and where they came from: *"The more information, the happier I am consuming it"* (Group8_07). Aspects of the cider-making process that consumers specifically liked or were interested in include natural fermentation methods, bottle-conditioning, making cider with "minimal interventions," or an otherwise unique production story: *"The thing that interests me with ciders is fermentation techniques… a lot of them are wild. And the yeast you can put into them to get these different almost textures out of it"* (Group7_02). Other consumers wanted to know where ingredients for cider were sourced from, the extent of preservative use, food-pairing information, geographical and climatic variables which impact cider quality, related historical information, and cider production time.

Most critically, the agricultural origins of cider motivated some consumers' interest in cider in the first place: *"Part of the draw to cider is here's apples. Here's the cidery. I mean, maybe that's romantic? That's okay. You get some of that with… wine. And I think less so with beer, you might have some breweries where they've got a row of hop vines, but you can make one batch of beer from, from all the hops that you've got growing there… So the connection to that agriculture piece, for me is a piece of it" (*Group13_05). Because apples constitute the core

of cider-related agriculture, the apple-to-cider agricultural transformation was a common topic of discussion both naturally and provoked. Despite the common knowledge that cider is made primarily from apples, consumers varied in their knowledge of – and interest in – apples as an agricultural product. In total, about one half of all consumer participants were aware of the existence of different apple varieties, including cider-specific apple varieties, in the first place. Generally, consumers in the Finger Lakes (NY) and Hudson Valley (NY) sessions were much more aware of apple varieties and the use of cider-specific apples in cider-making: for contributing more complex flavors, such as more acid and tannin, to cider products (Lea, 2008; Proulx & Nichols, 1980; Thompson-Witrick et al., 2014; Thornton, 2014). In contrast, consumers in Virginia and Vermont frequently did not have a clear understanding of apple varieties nor of individual varietal character as it is expressed sensorially in a finished cider: *"I just think people don't understand the different apples as well as they do grapes, like you say this is a Merlot everybody knows what it is. You say this is a Pippin apple. No clue"* (Group3_06).

The consumers that were interested in apples were particularly interested in the history of specific apples, wild foraging, the sustainable uses of cull apples for cider-making, and the potential for apple varieties to promote agricultural biodiversity. Traditional style ciders, which focus on the use of cider-specific apples, may help to improve agricultural biodiversity by expanding the number of apple varieties used in cider-making (Miles et al., 2020; Soomro et al., 2022). Expanding apple biodiversity in turn may enhance economic sustainability for apple growers by creating more robust genetic material for apple farming and expanding markets for diverse apples with more complex sensory qualities (Alexander & Ewing Valliere, 2020; Miles et al., 2017; Peck & Knickerbocker, 2018). Consumer interest in the sustainable use of cull apples recalls findings from M. Smith et al. (2021) who found that sustainability and support for biodiversity are contributing factors in consumer valuation of American cider.

Following discussion about apple varieties and their different uses or contributions in cider, many consumers ultimately appreciated how different apples offered different sensory qualities, which they could use as inspiration for exploring other cider products: *"the idea that you could tell me about a specific variety that goes into this is really fascinating and knowing that, you know you like the Granny Smith taste and then you've got a matrix to be able to say like 'Oh so here are the ones that use Granny Smith, oh I'll try these.' And I'll stay away from the Fuji."* (Group1_02). Evidence of consumer interest in cider-specific apples aligns with research by Yennerall et al. (2020) who also reported similar findings in American cider.

It is relevant to elaborate upon how, in the current American cider food system, knowledge about agricultural production is not shared, common, cultural knowledge (Trubek, 2008) – particularly in regard to cider. In wine, knowledge about the product's origin and processing can be critical for how consumers make discernments about quality (Charters & Pettigrew, 2007; Trubek, 2008). In wine and other products, knowledge also serves to create connections between the consumption experience and the producer (DiStefano & Trubek, 2015; Labelle, 2004; Paxson, 2013). Cider-making information (i.e., the "cider story") can be a powerful tool in influencing consumers' valuation, particularly when consumers revere the values attributed to agrarian working and living. When consumers express interest in the background of cider, like other artisan products, the unveiling of production information makes cider into an *unfinished commodity* like that originally described by Heather Paxson (2013). As an *unfinished commodity*, the backstory of the raw material and cider-making process is value-

adding because it exposes the moral values and craftsmanship of a web of growers and producers; though not all cider-making is reliant upon time-intensive labor and staying true to agrarian ethics. Thus, the agrarian "cider story" must be present, accessible, genuine and dosed correctly in the right circumstance in order to appeal to consumers, add value, and spawn any reflective, meaningful sensory experience. Nonetheless, however, the flavor of cider seems to matter the most in terms of overall preference: *"I like that information. It's not necessary for me to drink the cider. But knowing… the little story about it… just makes it feel more special"* (Group5_03).

## Localness, Nostalgia, Community

In talking about the backstory of cider products, a recurrent theme for these consumers was knowing *where* a cider came from. Consumers heavily preferred their local cider: *"I feel like people care about local cider here because we have good local ciders"* (Group4_02); *"I like the idea of drinking local stuff"* (Group2_03). Consumers valued local cider out of the belief that local cider had superior intrinsic sensory quality – *"Before local cideries I didn't know there was dry cider. I thought it was Bold Rock or you didn't like cider and so I went to Charlottesville and went to Potters, and I was like, what? And so now I love it, but I hated cider"* (Group4_03) – while mass-produced ciders were viewed as sweeter, more artificial, and less of a place: "*I'll look at the bottle and go ah manufactured by Anheuser Busch, forget that. I'll throw it back because I want to support the local business and get a taste of a place to it"* (Group12_02). Extending off of previous discussion, consumers also tied local-ness to locally-sourced apples, noting their desire to support local orchards and local apple varieties: *"I like the idea of local apple varieties... I like getting the different varieties but I know nothing about them"* (Group1_05). Consumer preferences for local cider align with previous research highlighting American consumers' growing interest in local products (Bernard & Liu, 2017; Darby et al., 2008; Feldmann & Hamm, 2015), and specifically local cider (Farris et al., 2019; Jensen et al., 2021; M. Smith et al., 2021).

Interestingly, consumers often described "local" and "small-scale" cider producers synonymously and thus, many consumers preferred products also made at a small- or artisan-scale: *"I would lean more towards smaller local cideries… I tend to move away from the big ones"* (Group10_01). Supporting both local and small-scale brands was important to many consumers out of a desire to not *"support the machine"* (Group13_04). For example, in focus groups which occurred in the Hudson Valley (NY), Angry Orchard (technically "local" in Walden, NY, although owned by Boston Beer Company) was not described as "local" by participants, both because it did not have a community feel and because consumers believe that Angry Orchard did not and could not source *all* of their apples locally. Related quotes and observations suggest that consumers classify "local" cider as a product in which *all* of the *apples* are from within the state, if not within the immediate sub-region. These findings contrast evidence of "localness" being defined as the state within which the *cidery* is established (Farris et al., 2019) – in other words, the cidery business and the sourcing location of apples for cider-making are not always mutually inclusive, though consumers want them to be.

The importance that consumers place on local and small-scale cider represents a more general tuning of tastes away from those of industrialization (Belasco, 2007; Carolan, 2011; Trubek, 2008; Weiler, 2020). But, it is also critical to emphasize how consumers generally

preferred local cider for two specific reasons: 1) nostalgia and connectedness to *their* place, and 2) the increased community-oriented feel of local establishments.

First, consumers simply had a reverence for the area in which the research took place – their local area: *"I think it's interesting too, all of the ciders that we said were local… I like to choose local, but I was born and raised here. So I feel like that hits a little bit closer to home for me"* (Group4_01). But, for many, this pride was deepened by the research settings' regional cider history: "*It's special because it's uniquely connected to where we live. So it has a regional history and connection that maybe beer doesn't necessarily have"* (Group8_05). For example, consumers discussed how orchard-based cideries reminded them of pick-your-own establishments that they used to frequent as children growing up in the Northeast and they told stories of crabapple trees in their backyards and drinking fresh apple juice as a child, suggesting that consumers from the Northeast and Mid-Atlantic US have a uniquely sentimental connection to apples and American cider. These sentiments are in part suggestive of David Sutton's narratives of *gemeinschaft* and nostalgia (Sutton, 2001), but are also a step in creating a true, cultural *terroir* for products – consumers from rich apple-growing, cider-producing regions are "searching for their roots" (Trubek, 2008, p. 236) in the beverage that comes from the places they treasure, which Trubek (2008) articulates as *sentir le terroir* (p. 51). Others have described this phenomenon as "neolocalism" in the context of microbreweries (Flack, 1997; Schnell & Reese, 2003). Nostalgic sentiments help to ignite these consumers' interests in deepening their sensory experiences with American cider products because the social standard is to have an appreciation for the fine tastes and common knowledge associated with cider (Hennion, 2007). Further, local cider and apples enable social and emotional connectedness between the consumer and their agricultural surroundings through nostalgia and cultural specificity (see *Figure 2*), motivating consumers to explore the taste of *their* place.

The proximity of many consumers to cideries also influenced their understanding of cider- and apple-agriculture. For example, one consumer from the Finger Lakes (Group13_06) asserted that by supporting local cideries (inferred by the context of the discussion around the proceeding quote), you are supporting farmers: "*I mean, these places, you're really paying farmers, right? The people making the cider are growing the apples. They're just as much a farmer as they are a cider producer."* The assumption that cider producers are apple farmers comes from a *Finger Lakes* consumer because many cider producers in the Finger Lakes (NY) are also apple growers, which is much less common in Virginia and Vermont. In context, geographically proximity is well understood to influence nutritional food knowledge and access as well as cultural aspects of food identity, however here we affirm the social determinants of local cider preference (Eriksen, 2013; Farris et al., 2019; Hennion, 2007; Jensen et al., 2021; McDaniel et al., 2021) and how geographical proximity impacts agricultural knowledge and enables connectedness (Guptill et al., 2013; Labelle, 2004; Reddy & Flick, 1989).

Second, consumers preferred to engage with local cider and products made at a smaller scale because these products and tasting environments felt more community-oriented: *"You mentioned local and I think that's where it starts for me… I want to buy from a place that I can go and meet Mark or meet the folks from Citizen Cider and feel like it's part of a community"* (Group11_03). We emphasize consumers' preferences related to localness and connectedness in both *Figure 1* and *Figure 2*. Specifically, the cidery setting was a focal point of this community-oriented expectation with cider. Consumers in regions with many cideries enjoyed

traveling to cideries, most relevantly in the Charlottesville (VA), Hudson Valley (NY) and Finger Lakes (NY) regions. Consumers reported how visiting the cidery, whether a taproom or orchard, enables them to taste products before purchasing them – *"Yeah, we're lucky because of the amount of cideries that are here and the variety that we have… the single greatest source of information is talking to the people and just tasting things"* (Group5_02) – and allows them to get more information about how products are made for *"an equivalent trade in spending their money"* (Group11_02). Cideries were also described as being more welcoming and less pretentious (see *Figure 1*), compared to wineries and breweries, and cidery staff were often described as passionate and immensely knowledgeable. Lastly, consumers heavily valued meeting the cider-maker (often but not necessarily at cideries) as a way to build connection and validate the producer's production story: *"but for me John at Blackduck, his story, meeting him, it's like there's a whole relationship there"* (Group9_04).

The way that consumers describe their involvement in cider-drinking communities is distinctive but also analogous to other food systems. Gomez-Corona et al. (2017) noted that a social connection existed for industrial beer consumption, but only for the purpose of ethanol-delivery with friends. In wine, social factors are key for reflecting upon and discussing wine tastes with other tasters (Charters & Pettigrew, 2008; Weightman et al., 2019). Lahne & Trubek (2014) described extensively how social networks and nostalgic memories were at play in the sensory experience of Vermont artisan cheese, where consumers also engaged with farm stories, ethos of craftsmanship, and recommendations from others. With cheese in particular, hearing the "cheese story" is integral to the social dynamics of the cheese sensory experience (DiStefano & Trubek, 2015; Lahne & Trubek, 2014). But, as with the case of artisan cheese, only certain communities have an appeal for and find value in agrarian products made with an explicit level of care. Of course these tastes are constrained by social and cultural capital (Bourdieu, 1984; Paxson, 2013), but we suspect that nostalgia and community also plays into a regional, value-added narrative for American cider and potentially for other food and beverage products as well.

## Paying for Cider

Extending off of all of the previous themes, consumers had diverse opinions on how they financially valued cider and what they were willing to pay for different cider products. Some consumers were generally attracted to cider that was affordable and easily available (i.e., at the grocery store, see *Figure 1*) – making affordability and accessibility highly influential factors on purchase decisions: *"When I said earlier that I drink Angry Orchard… I don't have money to go out and buy fancy ciders all the time"* (Group7_01). In describing how cider should be cheap, one consumer said, *"I still put it [cider] in a category of cheaper than wine, maybe around the price of beer but still a little bit cheaper because it's apple… I don't know why"* (Group10_01). Interestingly, this statement aligns with research on European cider, where young consumers viewed cider as generally cheap (Fur & Outreville, 2022). Though many consumers expressed an interest in the agricultural connections underpinning the cider industry, this quote by Group10_01 also reaffirms the knowledge gap among some consumers regarding the apple-agriculture supply chain and the cost of apple-to-cider transformation (Trubek, 2008). In fact, this knowledge gap has also been identified by cider producers as a major barrier for the growth and profitability of the industry (Ostrom et al., 2022).

Many consumers described how the "cider story" was value-adding: noting that even though they innately preferred what was cheaper, they also wanted a product that was priced fairly and made with care and intention: *"The cheaper, the better. But I know you can't get that if it's artisanal so"* (Group10_02); *"Like there's value added in a story, that will usually make me part with a little bit more money"* (Group5_05). Similarly, consumers valued products that embodied respectable social and ethical standards. For example, consumers in one Vermont focus group were drawn to a tasting sample because its label declared the cider to pay homage to the producer's horticulture crew from Jamaica: *"I like that! A tribute to our horticulture crew from Jamaica who've been shaping our orchards for decades"* (Group11_03). In the same focus group, one consumer also said, *"I want a producer that's doing things the right way, is a good environmental steward… producers that say we're sourcing our ingredients from local farmers, or… we aren't using pesticides or harmful things in our products"* (Group11_02). Meanwhile, other consumers articulated the need for a cider story in order to justify higher spending on cider: *"I feel like there's gotta be an education with it too, for that more expensive price point. I'm not a consumer that's gonna go out of my way looking for an expensive bottle of cider. I'm looking for the four pack that's 12, 13 bucks typically. But I wouldn't be opposed to it if I was educated on the product"* (Group11_04). Exemplified through these quotes and others, consumers express a clear desire for cider producers and products that align with their social, cultural, and moral values, when those values are made clear. Further, these values create symbolic capital, as exemplified in the case of artisan cheese and cheese stories (DiStefano & Trubek, 2015; Lahne & Trubek, 2014; Paxson, 2013). Yet in this case, and as also described by Paxson (2013), we suspect that the present consumers' valuation of the "cider story" is in many ways a side effect of their regional cider heritage.

In keeping with these ideas, consumers also explicitly described a willingness to pay more for *local* cider: *"if it's local, I'm more likely to try it, even if it's a couple dollars more"* (Group3_06). Thus, the social networks created by locality, community, and nostalgia foster a sense of trust in and loyalty to local products. The social communities at work in cidery settings (and other proximally local retail settings), not only allow for the spread of product information and the cider story, but they also create social attachments that motivate consumer spending (see *Figure 1*). These observations hybridize ideas of social embeddedness in local and regional food systems (M. Granovetter, 2011; M. S. Granovetter, 1973; Hinrichs, 2000; Polanyi et al., 1957; Portes & Sensenbrenner, 1993) and Paxson's discussion of how "giftifying" a food commodity enhances the exchange value of a product (2013, p. 60) – where producers or retailers in the cider community share the stories about how cider is made, causing consumers to find value in the idea that a cider product was made by the hands of an identifiable being, from an identifiable local place, shared in a specific community by the giver themselves (see *Figure 2*). These ideas are also an extension of gift economies described by others (Hyde, 1979; Kimmerer, 2013).

Lastly, it is relevant to reflect on why some subjects in the present study were so willing and able to pay more for cider provided all of the values emplaced within it, while other subjects seemed completely oblivious to the agricultural and ethical values at stake in the American cider industry. As one consumer put it, *"If it's good, I'll pay the money"* (Group6_02); yet, this contrasts Group7_01's prior statement on how mass-produced, cheap cider is all that she can afford. Though these statements are both from people in the Hudson Valley, a prominent

orcharding and wine-producing region, the theme they articulate was shared by other consumers and potentially indicates a broader trend: cultural capital (Bourdieu, 1984) is at work in the American cider industry. Those who have a preference for complex-tasting, artisanal cider made from cider-specific apples may enjoy such taste experiences because they can afford them to begin with and they live in geographies and social communities where such styles of cider are normalized. Consumers who view the cider story as value-adding may do so because they have extra social and economic capital to give, enabling the taste of “artisan” or “complex” cider to be a marker of social class (Bourdieu, 1984; shown in *Figure 2*). And, these consumers *want* to spend their disposable income rewarding the skilled labor of a craft American cider producer because those empathetic desires have been regionally, culturally embedded within them. We showcase this relationship visually in *Figure 1*, describing how consumers are motivated to explore products in their area and prefer to buy many products at cideries themselves, when possible, because such behavior is the cultural, social norm. In summary, many cultural and social elements of geography influence consumer preferences and valuation for cider in the Northeast and Mid-Atlantic US.

### Limitations

While the present study aimed to thoroughly explore the preferences and perceptions of the cider-drinking experience, it is not without limitations. Firstly, the present sample of consumers does not include all consumers from the Northeast and Mid-Atlantic US, nor does it include the opinions of all American cider consumers living in or from the US. The methods used to recruit participants (e.g., university listservs, cidery social media platforms) for the present study can also be viewed as a limitation. Recruitment of participants through convenience sampling is a common approach for exploratory, qualitative research but may cause selection bias. We attempted to ameliorate this by hosting focus group sessions at a diverse range of different cider consumption settings and related settings, but we cannot guarantee that this ensured representivity. Lastly, this research is subject to the personal reflexivity of the research team, which had a critical role in the data collection, analysis, and writing processes. A more detailed account of the first author’s personal reflexivity is provided as *Supplementary Material II*.

## *Conclusion*

American cider is emerging as a popular drink in the alcoholic beverage marketplace, but not without the challenges characteristic of an industry young in its lifecycle. While consumer preferences for cider are evolving, much of the concurrent research on American cider has focused on production methods, economic valuation, and sensory profiling of cider products – leaving the preferences and perspectives of consumers still minimally understood. Using focus groups and reflexive thematic analysis, this research aimed to characterize consumer preferences of the cider-drinking experience in a select group of American cider consumers from three leading cider-producing states to take a “snap-shot” of preferences in the Northeast and Mid-Atlantic US cider industry. Our results provide relevant insights that support previous research on consumer sensory preferences and valuation of American cider products.

Altogether, these findings primarily showcase how consumers are driven to drink cider for its perceived reduction in negative health consequences and more desirable sensory qualities compared to other alcoholic beverages. Consumers' perceptions of cider quality are also heavily influenced by the drinking occasion, product information (i.e., the "cider story"), and their regional values; and, these extrinsic aspects of cider broadly influence consumers' valuation of cider. With these findings, cider consumers' sensory preferences and knowledge of the apple-to-cider agricultural transformation are also diverse. Nonetheless, the American cider industry is heavily based on social and cultural values; though these findings may be critically unique for geographies with apple-growing and cider-producing histories.

These findings are critical for the American cider industry by highlighting preferences which guide cider consumers. Producers and industry stakeholders may be able to leverage these findings to create and market products that better cater to consumer preferences and which foster more connectedness, economic fairness, and sustainability in the cider industry. However, more research is needed to better understand how the preferences discussed in the present study relate to the preferences of other cider consumers across the US, as well as to the preferences of consumers in the broader alcoholic beverage industry. Lastly, we present a call for more research dedicated to understanding how nostalgia and agricultural education in local and regional food and beverage systems elicits values-based approaches to food consumption and contributes to reflective sensory experiences in the US and beyond.

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## *Tables*

**Table 4.1.** Descriptions of the focus group settings and general group camaraderie. All participants sat in chairs, placed in a circle, unless otherwise noted.

| | Type of Location | Number of Participants | Atmosphere of Session |
|---|---|---|---|
| Group 1 | University, Blacksburg, VA | 5 | First session conducted; Participants included mostly graduate students, 1 librarian; session took place in the atrium of a University office building; most consumers appeared to be in their 20's. |
| Group 2 | University, Blacksburg, VA | 8 | Participants included mostly graduate students, two females that are close friends, one avid cider consumer from Roanoke, VA; Participants seemed surprised and overwhelmed by the cider information and preferences shared by the avid cider consumer from Roanoke; most consumers appeared to be in their 20's. |
| Group 3 | Urban cidery, Richmond, VA | 9 | Participants included two couples; 6/9 participants were Blue Bee cider-club members; multiple participants knew each other before the session; session took place in a covered area of the tasting room, away from regular cidery patrons; consumers varied in age substantially. |
| Group 4 | Orchard-based cidery, Keswick, VA | 10 | Participants included 2 mother-child duos, 2 friends; session took place in a reception hall at the tasting room, overlooking orchards, away from regular cidery patrons; all participants reported staying after the focus group to taste ciders at the cidery together; most participants appeared to be in their 20's-40's. |
| Group 5 | Rural cidery (no on-site orchard), Charlottesville, VA | 6 | Participants included one couple, beyond which no participants knew each other prior to the session; session took place in indoor area of cidery tasting room during non-business hours; participants were all avid consumers, 5/6 preferred cider (out of all other alcoholic beverages) exclusively; most participants appeared to be in their 30's and 40's. |
| Group 6 | Bottle-shop, Fishkill, NY | 10 | 9/10 participants knew each other prior to the session; session took place inside the retail store (display tables were moved to accommodate the session group sitting in a circle), near a tasting bar area, during non-business hours; Many |

| | | | |
|---|---|---|---|
| | | | participants were regular patrons of the retail shop; most participants appeared to be in their 30's and 40's. |
| Group 7 | Orchard-based cidery, New Hampton, NY | 8 | Participants included two couples; session took place on an outdoor deck in the front of the cidery's tasting room, during non-business hours. One participant worked at a nearby cidery as a bartender, one participant was friends with the host locations' cider-maker; two participants appeared in their 20's, 4 participants appeared to be in their 30's-50's. |
| Group 8 | Bottle-shop/Café, Rhinebeck, NY | 8 | Participants include 4 couples, 2 couples did not know each other prior to the session; session took place on an outdoor picnic table at the front of the retail setting; 2 participants owned the retail setting at which the session took place; all participants appeared to be in their mid- to late-30's. |
| Group 9 | Urban cidery, Hudson, NY | 7 | Participants included one couple, 4/7 participants knew each other prior to the session; session took place on two outdoor picnic tables in a covered outdoor space at the front of the cidery tasting room, during non-business hours; most participants appeared to be in their 20's or 30's. |
| Group 10 | Artisan food shop, Waitsfield, VT | 4 | No participants knew each other before the session; session took place in an enclosed focus group room, away from regular retail patrons during business hours; all participants appeared to be in their 40's or older. |
| Group 11 | Urban cidery, Stowe, VT | 4 | No participants knew each other before the session; session took place at a picnic table, in an outdoor area of the tasting room, away from regular business patrons, during business hours; all participants appeared to be in their 40's or older. |
| Group 12 | Urban cidery, Middlbury, VT | 4 | Participants included one couple, session took place inside the cidery tasting room during non-business hours; 2 participants appeared to be in their 20's, 2 participants appeared to be in their 50's or older. |
| Group 13 | Orchard-based cidery, Ithaca, NY | 8 | Participants included one couple and one mother-son duo; session took place under a tent at an outdoor cidery overlooking the cidery's orchards away from regular cidery patrons during business |

| | | | |
|---|---|---|---|
| | | | hours; most participants appeared around 30-40 years old. |
| Group 14 | Urban cidery, Rochester, NY | 8 | Participants included two couples; session took place indoors, inside of the cidery setting during non-business hours; most participants appeared younger than 30 years old; one participant had formal wine-education training. |

**Table 4.2.** Results of the demographic survey summarized based on participants counts. In total, 91 out of 99 participants completed a survey, including one missing response for Age and five missing responses for Income Range. The average age of all participants was 37.3 years.

| State | Count |
|---|---|
| Vermont | 11 |
| New York | 48 |
| Virginia | 32 |
| **Age Range** | **Count** |
| 21-30 | 28 |
| 31-40 | 38 |
| 41-50 | 10 |
| 51-60 | 9 |
| 60+ | 5 |
| **Gender Identity** | **Count** |
| Male | 39 |
| Female | 52 |
| **Income Range** | **Count** |
| $0-25,000 | 13 |
| $25,000-50,000 | 23 |
| $50,000-70,000 | 17 |
| >$70,000 | 33 |

# *Figures*

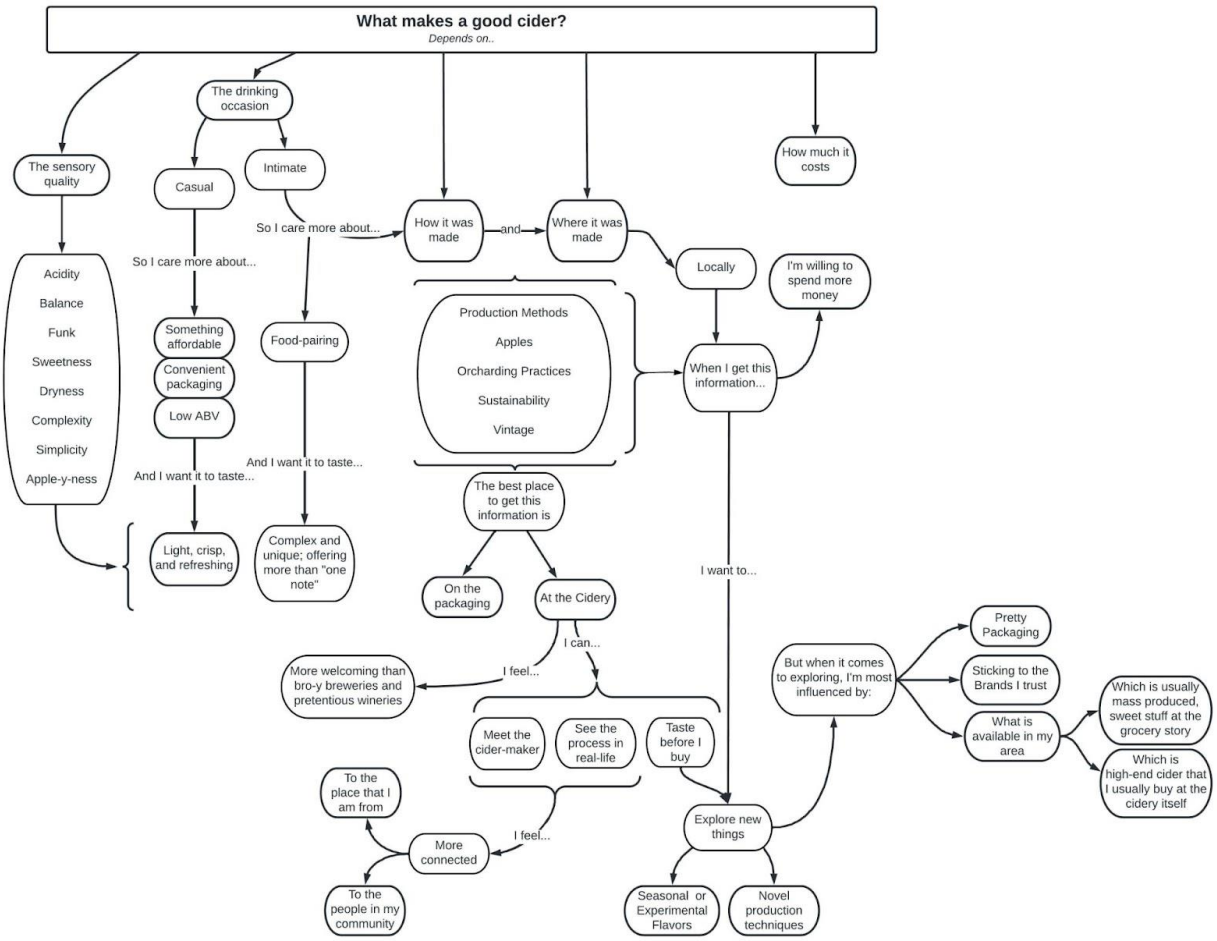


**Figure 4.1.** A choose-your-own-adventure for defining “good” cider. This graphic summarizes the majority of answers given by consumers to describe what makes a “good” cider, which was primarily answered in terms of sensory quality, the drinking occasion, product information, and price. Preferences for local products, the cidery setting, packaging, different types of cider products, and different flavors are also emphasized. Overall, consumer preferences for cider and ways of defining quality are diverse and heavily influenced by factors extrinsic to cider products.

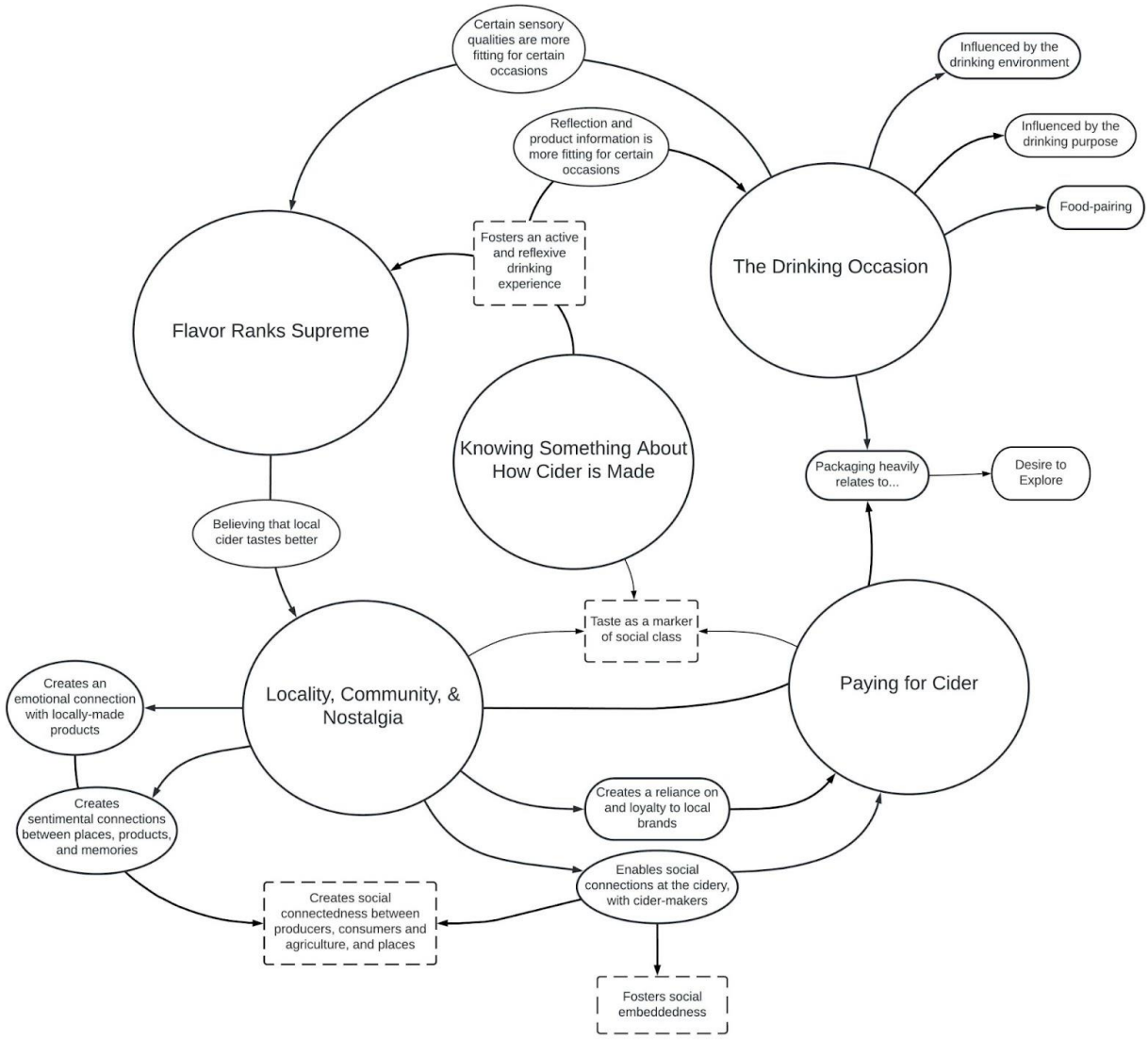


**Figure 4.2.** A flow chart showing the primary themes emphasized from the data. The larger circles indicate the overarching, primary themes and the square boxes (with dashed lines) indicate broader social theories, including models of active and reflexive taste experiences (Hennion, 2007; Teil & Hennion, 2018), social connectedness (Labelle, 2004; Paxson, 2013), social embeddedness (M. Granovetter, 2011; M. S. Granovetter, 1973; Hinrichs, 2000; Polanyi et al., 1957; Portes & Sensenbrenner, 1993), and cultural capital (Bourdieu, 1984), which contextualize the overarching themes. The descriptive ovals are supporting evidence and sub-themes.

# *Supplementary Material*

## Supplementary Material I

**Focus Group Questioning Route**

**Introduction**
Thanks everyone for coming today! Today we are going to discuss hard cider, and what you all like and don't like about them. We want to focus on hard cider, though you can of course compare cider to any other beverages that are out there. Remember, this is a super safe space and everyone's opinion about cider is perfectly their own! We can all discuss what we like and don't like here; there are no right or wrong answers.

**Opening Questions**
Let's start with going around the room and everyone can say their name and then tell us about your favorite cider ever…

**Transition Questions**
Thinking about *your* favorite cider, what stands out the most about that cider?

**Key Questions**
So, overall, what are some attributes of hard cider that you like? Dislike?

On a scale of 1 to 10 (where 10 means it matters very much and 1 means it doesn't matter at all), how much does it matter to you to know something about how cider is made?

- Why did you choose that number?
- Can you give me an example?

Who are some of your favorite cider producers? Why do you like them?

Imagine you find a new cider at the store; what makes you decide to try it?

- What does marketing or product packaging tell you about a cider?
- How do labels influence your expectations of a cider? What do you think cider labels should say?
- Do you prefer cider being in cans or glass bottles?
- How does price influence your opinion of cider, or your interest in buying a cider?

What do you get from the experience of drinking cider that you don't get from wine or beer?

- Do you view cider tasting as a more casual experience (like in a brewery where you choose your own flight) or a more structured experience (like at a winery where you have to sign up for a guided, intricate tasting session)?

**Tasting Questions**

*[transition/explanation]* Awesome! Now we are going to have our very own “mini” cider tasting. I’ll pour a few samples, show you the labels, and we will chat about everything. The goal here is to get you all describing these ciders with as much detail as you can. Everyone should have a clear cup and a red spit cup - I’m going to pour a 1-ounce taster into your clear cup. Go ahead and try the cider and gather your thoughts about it…. Please remember to spit out your cider samples into the red cup!

*[for each sample]*
What do you all think of this sample? How would you describe it?
What does it smell like? Look like?
What makes this cider unique or different?

**Closing Questions**
*[Summarize big themes: what people have generally said about a) how they pick cider b) the words they use to describe cider c) what makes cider so special/important]*

What have we not covered or talked about that is important about cider and your experiences drinking cider?

Is there something you’ve been wanting to say that you haven’t gotten to, for whatever reason?

Does anyone have any suggestions for me or questions about our time today?

## Supplementary Material II

**Reflexivity Statement**

Qualitative research considers knowledge as reflexive and subjective; which is to say that researchers unconsciously use their unique perspectives and experiences to inform the knowledge that they produce. My reflexivity highlights my past experiences and how they contribute to my views and assumptions as a qualitative, American cider researcher and trained sensory scientist.

I grew up in North Carolina, raising in a small, middle-class Italian and English family. As an Italian American, I have vivid memories of eating glorious amounts of my mother's incredibly delicious, homemade Italian food. As the only child of working parents, I also spent most of the quality time that I got with my parents over a table of food. My other food-oriented childhood memories include eating biscuits and gravy, spitting watermelon seeds as far as possible, and picking and eating fresh strawberries in the early summer. Food and beverage have always been fixtures in my and my family's life, which spawned my passion for baking and led to a short professional baking career in my early 20's. As a baker, I discovered the awe and lure of fresh baked goods and became drawn to the story and culture around food. I had meaningful relationships with other specialty bakers and service industry colleagues: a community that valued the history, context, process, and place of alcoholic beverages, among other artisan food products. After many sleepless years of baking and going to graduate school part-time, my mentors (a team of applied ecologists at North Carolina State University) urged me to stay in school, and so I found a mentor at Virginia Tech who not only was also an ex-service industry cook but who also valued the cultural identities and communities that centered around food. Together, we believed that food culture could impact the sensory experience in broad, unique, and unknown ways; and so, with little convincing, I was off to Virginia Tech to get a doctoral degree studying an alcoholic beverage I knew nothing about - hard cider.

Before being assigned a project that aimed to investigate the consumer and producer perspective of American hard cider, I had consumed cider from one producer in my lifetime: Stem Cider, made in Denver, Colorado. I had heard of other big cider brands like Angry Orchard, but cider had never appealed to me. As I forged ahead to plan and conduct cider research, I began to meet and talk with more and more cider makers: some new to the field, some inspired by an old apple press from a family friend, and some veterans with a stern passion for cider apples and sustainable orchard management. I traveled to beautiful and complex places; orchards far from the beaten path, cidery taprooms with underground caves and mountainous murals, winding roads lined with acres of apple trees, and backyard orchards overlooking the Adirondack Mountains. Over the course of this project, I grew to understand American cider as treasured, storied, and complicated. I view my research through a unique lens - glorifying cider because of all the beautiful places and faces. I have grown to empathize with cider-makers for their hard work behind the scenes. And I have become enamored by the sensory complexity and diversity that American cider has to offer – having tasted hundreds of different ciders, many of them for free. Last but not least, I've come to believe that the resilience, grace, and value of cider is in the apples – a painstakingly undervalued agricultural commodity.

The purpose of this reflexivity is to emphasize this: my experience working in the service industry and coming from a family that loves food means that I place a lot of emphasis on where a food comes from, how it is made, and who made it. These things make food meaningful to me. I am able to care about these things because of my privilege – I can afford to buy food with a preference for where it came from and who made it, I am small and healthy enough for any food indulgence I may want, I have lived in places with ample accessibility to unique and affordable food options. Most fundamentally, my research involved a cider road trip that was afforded by the university through which I conducted the research, and which was completed without a hitch. My viewpoints of food and of American cider, which I convey in the present work, is from a place of immense privilege that heavily informs my analytical approach to the research.

# Chapter 5 – “Apples cost more than water.” Exploring producer perspectives of American cider in the Northeast and Mid-Atlantic United States


## *Abstract*

American cider is growing in popularity, particularly throughout the Northeast and Mid-Atlantic regions of the United States. While research has investigated the American cider industry in a multitude of ways, including supply chain dynamics, consumer preferences, and sensory quality, less is known about cider producers’ opinions and beliefs relative to the products that they make. How do American cider producers value and emplace value onto cider as the industry grows and competes with the broader alcoholic beverage market? This study aimed to explore producer perceptions of American hard cider using a phenomenological qualitative approach. The research comprised 21 semi-structured interviews with cider-makers throughout Virginia, Vermont, and New York, three leading cider producing states in the Northeast and Mid-Atlantic United States. Interview sessions were subject to inductive thematic analysis for themes broadly related to preference, the cider-drinking experience, the cider-making experience, and the cider industry as a whole. Results of the study suggest that cider producers broadly prefer complex flavors and cider made with cider-specific apples. Yet, cider producers are host to a diverse spectrum of values related to the cider-making process, agricultural economics, and business goals: all of which extend to producers’ personal cider-drinking preferences and the cider experiences that they create for the public. Simultaneously, the research discusses a chasm in how American “cider” should be defined, as well as other barriers in the nascent cider industry. This research has broad implications for domestic cider and apple agriculture industries, as well as serving as a template for bridging the divide between producer and consumer-based food studies.


## *Introduction*

Alcoholic cider, known as hard cider in the United States (US), is growing in popularity worldwide (Bundele & Deshmukh, 2022) and particularly experiencing a renaissance in the US (Fabien-Ouellet & Conner, 2018; Jacobsen, 2021, 2022; Kline & Cole, 2017). Though the American cider industry has grown substantially in the past decade, profit margin of the cider industry today is plateauing as consumer preferences evolve to value small and local brands in place of national staple brands (Lombardo, 2020; Wood, 2022). Indeed, regional and local brands as well as small- and medium-sized cider producers constitute the majority of the cider industry in the US, supporting local and rural economies (Brager, 2019; Peck & Knickerbocker, 2018). Even large, commercial orchards are beginning to cater to the increased demand for apples grown solely for the purposes of cider-making (Merwin, 2015). The Northeast and Mid-Atlantic US in particular is seeing the most growth in the number of cider producers in recent years (Brager, 2019), and the region has a rich apple-growing and cider-making history (Calhoun, Jr., 2010; Pucci & Cavallo, 2021; M. Smith & Lal, 2017). New York, Virginia, and

Vermont currently rank 1st, 8th, 12th respectively, as states with the most cideries (Conway, 2019, 2020; E. West, 2018). The number of cider producers is expected to increase in the next few years as cider consumers seek to explore new, “eclectic" varieties as opposed to big-name brands (Wood, 2022).

Research to date has focused mostly on how to define objective elements of cider quality: the chemical composition of apples and cider (Boudreau et al., 2017; Ma, Neilson, Lahne, Peck, O’Keefe, & Stewart, 2018; Rosend et al., 2019; Thompson-Witrick et al., 2014), cider production and processing methods (Alexander et al., 2018; Keller et al., 2004; Techakanon & Sirimuangmoon, 2020), fermentation quality and techniques (Calugar et al., 2021; Cousin et al., 2017; Littleson et al., 2022; Rosend et al., 2019; Valles et al., 2007), and sensory profiling of ciders made according to different techniques and from specific regions (Kessinger et al., 2020; Littleson et al., 2022; Phetxumphou et al., 2020). Research has also investigated how consumers value a variety of factors that are intrinsic and extrinsic to cider products in the US (Cole et al., 2022; M. Smith et al., 2021; Tozer et al., 2015; Yenerall et al., 2022). Recently, Miles et al. (2020) and Ostrom et al. (2022) explored the supply chain of cider production in the US, trends in cider production and apple agriculture, and barriers that cider producers face on their path to success and a profitable livelihood in the cider industry. Cider producers' interest in geography-based quality designations and the proliferative use of cider-specific apples has also been documented (Fabien-Ouellet & Conner, 2018). While both consumer-focused and producer-oriented research is critical for growing industries and trouble-shooting barriers to success (Bruwer et al., 2011; Desmet & Hekkert, 2007; Schifferstein, 2009; Spence, 2020; van Kleef et al., 2005), researchers have neglected to fully investigate how cider producers view cider quality holistically.

Cider can be made according to a wide array of methods, contributing to cider quality. The Alcohol and Tobacco Tax Trade Bureau requires a finished cider product in the US to be made from 50% apple juice or apple juice reconstituted from concentrate (27 CFR § 24.332 - Hard Cider Materials, n.d.). Cider can be made over different lengths of time, aged for different lengths of time, utilize inoculated or wild fermentation methods, utilize natural or forced carbonation methods, and more unique production processes. Cider can also be made from any of the many different types (varieties *or* cultivars) of apples grown in the US. Traditionally, apples are classified as either dessert or table apples (known for their sweetness and often sold in grocery stores), cooking apples, or cider-specific apples (intended for fermenting into cider). Ciders made in the US can be made from dessert or culinary apples that do not meet fresh market standards or are otherwise waste (i.e., cull apples), while other ciders can be made mostly or exclusively from cider-specific apples. Cider-specific apples have been historically prescribed for cider-making because they can contribute complexity, bitterness, astringency, and body to a cider beverage, alongside other fermentation methods (Alexander & Ewing Valliere, 2020; Calhoun, Jr., 2010; Lea, 2008; Proulx & Nichols, 1980). Apples are analogous to grapes used for wine-making: geography, orchard practices, seasonal climate, and many other factors can impact the sensory expression of an apple and the ultimate cider (Brennan, 2019; Ma, Neilson, Lahne, Peck, O’Keefe, & Stewart, 2018; Ma, Neilson, Lahne, Peck, O’Keefe, Hurley, et al., 2018; Merwin et al., 2007; Proulx & Nichols, 1980).

## Cider History

Apples have been grown throughout North America for centuries (Fulton, 2003; Kerrigan, 2008; Volk & Henk, 2016), yet American cider has a complex history that continues to have effects for apple agriculture and cider-making today. Apple-growing originally began with indigenous populations in North America who grew crabapples (Abrams & Nowacki, 2008; Kerrigan, 2008). Early European settlers brought apple seeds and began to grow apple trees in rows (i.e., orchards). Apples were a moderately shelf stable, versatile fruit that could be eaten fresh, used in cooking, or fermented into cider which was in many cases safer than water for early American colonists to consume (Aaron & Musto, 1981). American-made cider and apples were also a valuable export crop, and it is estimated that by the 1800's almost every home in colonial New England sustained an apple orchard (A. F. Smith, 2014). Cider was seen as simultaneously the "poor man's drink" and the US Founding Fathers' beverage of choice. At the same time, slave labor is believed to have been critical for sustaining plantation orchards and improving cider quality. Though much remains undocumented, Thomas Jefferson was known to be an avid cider consumer and trades-man who relied heavily his slaves Jupiter Evans and George and Ursula Granger to lead the cider-making process at Jefferson's estate, Monticello (Hayes, 2021; Stanton, 2012). Even during colonial times, different apples from different regions were known to yield ciders of different quality and flavor (A. F. Smith, 2014).

With Prohibition, many New England orchardists began cutting down their apple trees as American cider production was outlawed. Post-World War II efforts call for the American food industry to focus on increasing the volume of food production, shifting the focus of apple agriculture to favor large production volumes of easy-to-grow, eat, and store apples, with a reduced focus on apples intended for turning into alcohol (Futrell, 2017). Simultaneously, importing apples, juice, and juice concentrates from Europe and Asia became more affordable and easier than the time, expenses, and hard labor of growing apples domestically (Futrell, 2017).

This abridged timeline of events has led to American cider's current state of affairs: many large, commercial orchards producing primarily table apple varieties, a low supply of apples for cider making (Becot et al., 2016; Fabien-Ouellet & Conner, 2018), heirloom apple varieties that are becoming rare or completely extinct, labor shortages and discrepant pay for orchard and cider-production staff (Weiler, 2021), and the pervasive use of apple juice concentrate for cider fermentation (Miles et al. 2020), among other problems. At the same time, however, apple agriculture and subsequent cider production can be a profitable, and sustainable entrepreneurial endeavor as well as a potentially meaningful livelihood (Becot et al., 2016; Peck & Knickerbocker, 2018; M. Smith & Lal, 2017).

## Why study producers?

Understanding how producers view their products from the perspective of consumption is novel. D. Goodman and DuPuis (2002) discuss how most investigations into the social networks of production and consumption within agricultural and commodity studies have often separated "how we grow food" from "how we know food" (D. Goodman & DuPuis, 2002, p. 6). In such, ample research has explored "how we know food" in the context of consumption while others have explored production in terms of "what is grown, made and sold, and on what

economic terms" (Warde, 2016, p. 13). These differences, as scholars report, have contributed to a knowledge gap between production and consumption (M. S. Carolan, 2011; D. Goodman, 2002; D. Goodman & DuPuis, 2002; Guthman, 2002; Warde, 2016). Some research has begun to bridge this gap, however, by interrogating producer practices and the sentiments that define both 'good' and 'bad' production (M. Carolan, 2022; M. K. Goodman et al., 2010; Lahne & Trubek, 2014; Paxson, 2013; Trubek, 2008), as well as what 'good' and 'bad' production sentiments convey to public consumers. Though understanding how and why producers make food and beverage products 'good' for both their business and their livelihoods is increasingly being explored, we suggest that more focus must also be given to questioning how producers "know food" in the context of *their* consumption and how *this* impacts consumers.

Producers and their products embody values that appeal to different consumer needs and which create emotional, cognitive, and social connections (Dare et al., 2013; Paxson, 2013). In other words, Trubek (2008) has described how taste producers and tastemakers were fundamental in shaping agrarian foodviews among the French community, which has broadly evolved to taste and value wine and food uniquely (Trubek, 2008, p. 21). Therefore, we suggest that producers may influence consumer values by embedding their own ethical standards onto the products that they make based on what they personally like to consume, and that this behavior conveys a certain expectation of quality to consumers.

Producers are often assumed to be extremely educated and long-immersed in the industry in which they engage; but they can also be new to their industry, transferring the ethics and ideals of their other careers and prior lifestyles into their newfound industry. As such, different producers may have conditioned or evolving definitions of quality in terms of what they make, how they make, what they taste, and how they taste. Sensory research has been critical for exposing the ways in which expertise influences how one discusses and prefers foods and beverages (Ballester et al., 2008; Hopfer & Heymann, 2014; Langlois et al., 2011; Schiefer & Fischer, 2008; Souza Gonzaga et al., 2020; Wang & Spence, 2019). Producers can be unique in their approach to discerning and discriminating quality with wine, as an effect of their product expertise. Using the growing, renewed US cider industry as a platform for investigating the consumption perspectives of producers, we suspect that exploring producer preferences, expertise, and views of quality will help to expose how producers influence foodviews beyond simply making products to begin with.

The current research aims to use phenomenological, qualitative research methods (semi-structured interviews) and reflexive thematic analysis to explore how a sample of professional cider producers in the Northeast and Mid-Atlantic US prefer cider and view cider quality and the cider-drinking experience. The research design and analysis is underpinned by a critical realist ontology and a contextualist epistemology, which maintain that all of the collected and discussed information about cider producers' preferences represents multiple realities, viewed and understood by multiple researchers from multiple backgrounds, all of which can be simultaneously unique and shared (Braun & Clarke, 2013). These theoretical assumptions contend that all of the experiences described in the research are true, valid, and real for the participants involved in our research in the geographies where our research was conducted, and as inferred uniquely by our team of researchers (Braun & Clarke, 2013; Madill et al., 2000; Tebes, 2005). This means that while our interrogation of cider producers and their experiences

may or may not be generalizable to wider populations, is not perfectly reproducible, and our findings may or may not be representative of broader trends in the US food system.

## *Methods*

Interview sessions were conducted throughout Virginia, Vermont, and New York between February and August 2021, in part to accommodate social gathering restraints due to the COVID-19 pandemic. Interview participants were recruited via direct email, and all research sessions for this study were approved by the Virginia Tech Institutional Review Board (IRB # 20-880). In total, 58 cider producers were contacted. All subjects gave their informed consent for participation. The only screening qualification for cider-makers to participate in the study was that they were a professional cider-maker for a company, not just an owner or not-for-profit hobbyist; otherwise, cider producers could have been any age, have any level of experience in cider making, and produce cider at any scale.

Most interviews occurred in-person at the respective cider-makers cidery or taproom. In cases where it was not convenient or safe for the cider-maker to have an interview at their facility (due to the COVID-19 pandemic), interviews occurred via Zoom. All interviews were moderated by the first author (MDC). Producers were asked to complete a brief demographic survey, which asked questions related to age, gender, and years of professional cider-making experience, immediately prior to participation in the interview. Interviews followed a semi-structured questioning route, provided as *Supplementary Material I*, that asked questions about the cider-making process, economic factors relevant to the cider industry, non-apple flavorings in cider, historical barriers to inclusivity in the cider industry, and valued sensory qualities. Recent research and evidence in the popular press suggests that all of these factors are important components of the current cider and broader alcoholic beverage industries (Brennan, 2019; Ostrom et al., 2022; Sugrue & Dando, 2018). All interview sessions were audio-recorded and transcribed. The present study was approved by the Virginia Tech Institutional Review Board (VT IRB #20-880), and all participants gave their informed consent prior to participation.

### Data Analysis

After transcription of all sessions, data was analyzed using NVivo 12 software (QSR International Pty Ltd., 2020). Data analysis was conducted using an inductive approach, exploring themes conveyed through the participants' discussions without a pre-established theory. The researchers aimed to uncover producer preferences and perspectives that encompass and extend beyond the moment of cider consumption. Data analysis followed the steps of reflexive thematic analysis (Braun & Clarke, 2006, 2013): familiarization, coding, developing themes, and writing. All interviews were transcribed verbatim by the first author (MDC). First author familiarized herself with the data through reading all transcripts and re-listening to all audio-recordings, and subsequently generated both initial codes and secondary sub-codes. Second author (JL) read all interview transcripts for familiarization. Together, first and second authors discussed all relevant codes and supporting quotes to generate overarching themes. During the writing process, themes were refined further primarily by the first and second authors.

# *Results & Discussion*

A total of 21 professional cider makers participated in 20 interviews (6 in Virginia, 5 in Vermont, 9 in New York), ranging in length from 37 to 77 minutes. Five interviews were conducted via Zoom in part to accommodate travel and social gathering constraints due to the COVID-19 pandemic. One interview included two cider makers, who shared one cidery together, and one interview transcript was lost due to poor internet connectivity at the orchard where the interview took place. Of the cider makers that participated in an interview, 3 were female and 18 were male. Cider makers reported a range of 1-23 years of professional cider-making experience, with an average of 7.5 years.

Four primary themes summarize the cider makers' varied perspectives of the cider industry as a whole, as well as their preferences for cider products and the cider-drinking experience: ***The Drinking Occasion***, ***Flavor Ranks Supreme***, ***Value in a Story***, and ***Apple Economics***. Within the three latter themes, the cider producers' varying approaches to and perspectives of cider-making overflowed into their beliefs about flavor, product information, and the agricultural economics embedded within the cider industry and drinking experience. The following sections intend to paint a thick, rich description of the phenomenon of both cider-making and cider-drinking, through the eyes of professional cider makers. We begin with a discussion of ***Cider-making Philosophies*** which were heavily influential on the themes that we identified. This is then followed by discussion of the four overarching, dominant themes and their respective subthemes. We also provide excerpts from producers' loquacious discussions, contextualizing how cider makers' preferences relate to each other, consumer perspectives, sensory science, and other social theories relevant to the food and beverage industry.

## Cider-making Philosophies

Cider makers had broad, varying philosophies on how cider should be made and the purpose of their cider. Just as the ACA, industry stakeholders, and researchers have pioneered "modern" versus "traditional" styles of cider (Alexander & Ewing Valliere, 2020; United States Association of Cider Makers, 2018), cider producers discussed in depth how these styles of cider products closely paralleled approaches to cider-making. We describe the approaches, or philosophies, of cider-making as a spectrum because many producers often had opinions that hybridized both modern and traditional approaches given their individual access to resources, economic position, social embeddedness within the community, and their business goals.

### The Purist Approach

In the "traditional" or "purist" approach to cider making, producers utilized primarily or exclusively cider-specific apples, concerned themselves with how and where those apples were grown, and wanted firmer regulations on the definition of "cider." These sentiments were expressed passionately by NY_Producer01, *"the thing I want the most for cider is for it to be more transparent than it is, and it is deeply unfortunate that things can be called cider and only have 51% apples and apple based products and it's outrageous,"* and NY_Producer08, *"but the stuff that's like half concentrate base stuff and half artificial flavors, that shouldn't even be called cider"* Extreme purist producers extensively disliked flavored ciders, noting how they *"always feel like a novelty to me"* (NY_Producer01), how *"cider should taste like cider"* (VT_Producer18),

and how *"the varieties themselves is what creates flavors"* (NY_Producer08). Traditionally, cider is defined as fermented apple juice (Lea, 2008; Proulx & Nichols, 1980), and so many purist-tending producers believe that beverages called "cider" in the US should be consistent with these values and have specified limitations for how much sugar or other ingredients can be added, before the beverage is no longer legally called "cider." In addition, these producers often preferred cider apples to be grown sustainably and biodynamically.

Some producers tending toward the purist approach only liked using natural adjuncts, or native herbs, fruits, or botanicals in their products: *"I mean, they're fun. It's not my direction. You know, I would like to work more with infusions, you know, of using, you know, herbs, whether it be [sic] like lemon balm, African blue basil, you know, mint you know doing something like that rather than an adjunct"* (VA_Producer12). Nonetheless, even purist-leaning producers noted how the use of adjuncts in cider allows producers to have a more diverse repertoire of products, and overall these types of producers were still adamant about not letting such flavors overtake the natural integrity of the product: *"Our philosophy is the cider should speak for itself and not be upstaged by additions to it. So if the additions complement it and enhance the flavor and don't overpower it and we're open to trying it out"* (NY_Producer03).

In following these sentiments, nearly all purist producers emphasized how little they aimed to intervene with the cider process including the thoughtful and intentional use of sulfites, the avoidance of exogenous acids or tannins, filtering or fining agents or equipment, and yeast nutrients. Producers tending toward the purist approach wanted their cider *"to communicate with consumers the beauty and uniqueness of a place where apples are grown"* (NY_Producer01). Ultimately, these producers attempted to and wanted to manipulate the cider fermentation process as little as possible because their ultimate goal in cider-making was to facilitate the expression of *terroir* – the French term for "the taste of place" – in the ciders that they made. These ideals are indicative of artisan approaches to food and beverage production, where artisan foods can be linked to "minimalist" or empirical modes of production in order to best convey authenticity (Leissle, 2017). Of note, many purist cider producers were often not reliant on their cidery for an income or were less motivated by purely business success, and these producers were less interested in appeasing consumer desires with the products they made. Rather, these producers were often intrinsically motivated by their personal interest in the cider-making process or using the resources of their land. We discuss these value-systems more in depth in later sections.

*"Remove myself from the process as much as possible like minimal inputs like I would love. Right now, I use a little bit of um I add a little bit of commercial yeast, in part of the product. But I would like to move toward using wild yeast more and more I use a little bit of sulfites but it'd be great to use less sulfites."* (NY_Producer07)

*"It's not a matter of what I do [sic] it, it's a matter of what I don't do to it."* (VA_Producer15)

### The Experimentalist Approach

In contrast to purist cider-makers, we term the other main group of cider-makers "experimentalists," because these producers often used apple juice as a base for adding non-

apple flavors or they enjoyed experimenting with the cider production process. In this way, experimentalist producers seemed to drive modern style cider production, as four interviewed producers made exclusively modern-style cider. Many experimentalist producers preferred to use table or dessert apples for cider-making because these types of apples contributed lower tannins and overall less complexity, making them more conducive for flavoring. These producers were personally interested in the craftsmanship of combining and creating different flavors in cider, regardless of the where those flavors originate: *"I'm just trying to explore really interesting flavors, and I see the apple as a great vehicle for flavors because unlike beer, which has like malt and all these other things that get in the way of fruit, you're starting with fruit and cider is pretty thin to begin with when you ferment it all out the dryness."* (NY_Producer04). In such, these producers often spoke about how the lack of clear guidelines and regulations in the US cider industry allows them to be creative with their adjuncts. One producer specifically emphasized his desire to see the cider industry expand beyond the minimalist, traditional approach to cider making, saying *"I think the industry has to open up more to what cider is or what it can be"* (NY_Producer02).

Of note, many experimentalist-leaning producers aimed for consistency in their products from batch to batch and season to season. From a business perspective, they often emphasized a desire to *"capture a certain demographic"* (VT_Producer17) or follow *"what's trending"* (NY_Producer04). Many of these producers emphasized how flavored ciders are more profitable: *"adding adjuncts, adding hops, adding other fruits and showcasing other sides and I get that, you have to do that to pay your bills to keep the lights on, and those are the products that often enable producers to do some of these finer small higher value more premium things"* (VA_Producer14). In other words, these producers paid much more attention to profitability and business growth in producing ciders that appealed to consumer trends, even if that meant going against their own preferences: *"I don't typically drink sweet cider, I don't really like sweet cider, but we could be a tenth of our size making only dry cider and kind of struggling as a business, or we could be giving people what they want, and people like sweet"* (NY_Producer10). Further, many of the producers that focused on more experimental or commercial production practices often personally preferred the flavors of more traditional, complex ciders.

*"I personally love them either, you know, British ciders especially because there's so much different from what we make their [sic], you know, flabby. They're like leathery, they're band aid, they're f***** up but I love them because they're so interesting. But I don't think the American consumer is ready for that"* (NY_Producer04).

*"For more modern style cider just in the sense that, you know, it is kind of clean all the way through, doesn't have, you know the phenols, you know that the heirloom fruits produce that maybe require a bit more educating or a bit more of a sophisticated palate at this point in time, you know, we find the ciders that we make from dessert fruits to be a bit more approachable, especially for, you know the general consumer."* (VT_Producer20)

One experimentalist cider-maker whose production efforts focused on modern style cider emphasized the flexibility offered by apples kept in cold-storage versus those available annually: *"Apples are storable all year long, you know winemaking on a vintage schedule was very time intensive that harvest, and then stretched out for the rest of the year… what was really fun about apples and storability of apples is that you can be putting up a fermentation every two weeks all year long."* (VT_Producer17). Two cider-makers emphasized how the use of cull dessert and table apples as an invaluable avenue of sustainability in the American apple and cider industries: "*cider exists as a recovery, recovery for apples that can't be sold at fresh market, which, which took me a long time to really understand that and realize that it's a, it's a unique place."* (VT_Producer17).

Two experimentalist cider producers preferred to use juice from concentrate for cider-making as opposed to fresh apple juice. These findings are consistent with other research suggesting the use of juice concentrate in hard cider (Miles et al., 2020; Ostrom et al., 2022; Raboin, 2017; Snyder, 2018); however, the total number of cider producers in the US that rely on apple juice concentrate for making cider is not well-documented.

### The Middle

A spectrum of cider-making philosophies creates space for those producers who hybridized both purist and experimentalist approaches. For example, some producers made traditional style ciders that highlighted rare, specific apple varieties or apples specifically from local or regional places, *and* flavored products or experimental fermentations. One such producer cited a philosophy of using apples: where rare or wild-foraged apples would deserve minimalist, purist processing into cider (i.e., no added sulfites) while orchard- or commercially-grown fruit can rightly have anything added to it or can even require chemical interventions to enhance overall flavor. Still, some producers advocated that even if they just want to create a good base for fermentations, they strive to maintain some standard of apple quality: *"What I've learned in the cider industry is, if I'm going to concentrate on heritage styles, traditionals the apples are more important. What I have learned is if you're going to add adjuncts, you just need a good base."* (NY_Producer02). These ethos of cider-making, which are heavily rooted in the quality and integrity of the apples, are comparable to those described with artisan cheese by Lahne and Trubek (2014), H. G. West et al. (2012), and Paxson (2013); ethical values about how apples should be treated or how apples are grown are then carried through into cider-making. Wild, rare or untreated apples undergo a minimalistic, hands-off process, while commercially-grown, domesticated, sprayed, or fertilized apples undergo an equivalently manipulated, commercialized cider-making process. Middle-of-the-spectrum producers prioritize the flexibility to change the cider product that they make so as to be more of an experimentalist or more of a purist. These types of cider producers spoke about how they made some products over extended periods of time with exclusively ciders-specific apples and unique production methods, and how they made other products with wholesale dessert apples, non-apple adjuncts, and different domesticated microorganisms – both of which *types* of products they enjoyed making and drinking. In doing so, these producers make use of different types of apples for the purpose of cider-making which expands their repertoire of cider products and allows them to fluctuate their agricultural values based on the integrity of the raw material and the desired goal that they have for their end product.

These examples of how producers vary in their approaches to the cider-making process are pertinent because each cider-maker's approach influenced their view of good cider, how cider should be priced, the importance of the agricultural processes underlying the cider industry and cider production, apple and cider economics, and their viewpoints of barriers in the cider industry. All of these ideas are further elaborated upon in proceeding sections.

## Flavor Ranks Supreme

When asked what makes a cider good or bad, cider sensory qualities were a top priority. Foremost, producers spoke at length about their desire for balanced flavors, particularly with acidity, sweetness, tannins, and alcohol. Alcohol should not be too strong in a cider, making it "hot" and masking other flavors. Intense tannins, causing harsh astringency, should be balanced with a touch of sweetness, and a cider should not be both intensely dry and acidic at the same time: *"there's so many different ways you can do balance. It could be bone dry, but then it needs acid, or it could have sugar left in it but then it really needs some tannins, to, to balance that has to have some nice aroma to it"* (NY_Producer08). These findings highlight the importance of polyphenol content, dryness, sweetness, and acidity in the cider sensory experience, which are also all well documented features of the wine sensory experience (Fontoin et al., 2008; Ishikawa & Noble, 1995; Martin et al., 2002; Nolden & Hayes, 2015; Symoneaux et al., 2014). Though some producers noted that they can *"still appreciate a well-made sweet cider"* (VA_Producer11), all producers emphasized a preference for dry cider.

At the same time, many cider producers noted their appreciation for relatively low levels of "funky" and "acetic" flavors for their ability to create a rounded, overall "good" flavor. Producers noted that these flavors, when not dominant, add to the "chord" of a good cider; however, producers also emphasized with consensus that serious or intense faults or flaws can make a "bad" cider. These findings are consistent with Alexander & Ewing Valliere's description of traditional ciders, which can include some non-dominating spicy, smokey, farmhouse, cheese, butter, olive, and phenolic flavors (2020, p.34). A quantitative measurement of these flavors and their acceptable intensities is not documented in scientific research. Off-flavors that producers explicitly described in cider included: "watery" or "weak" overall flavor, 'fingernail polish" and "sulfuric" aromas, "plastic" or "rubbery" flavors, intense sweetness, intense "acetic acid" flavor, intense "wood-like" flavors, clear cider (i.e., visual attribute), and "metallic" flavors. One Vermont producer also expressed concerns over how the range of complex, fault-associated sensory qualities in the cider marketplace makes it hard to discern standards of quality in the industry as a whole. These sentiments closely mirror those of the artisan cheese industry wherein variation within products can stem from material or environmental conditions (i.e., *terroir*), or poor workmanship, and that the two root causes can be easily conflated without clear sensory quality standards (Paxson, 2013, p. 155). Evidence of producers appreciating low levels of traditionally faulted sensory qualities (Lea, 2008), but also disliking other bad flavors with consensus suggests that more research may be pertinent to define cider sensory faults, their origins, and methods for controlling them.

At the same time, many producers noted that they want a cider with various aromas and flavors, *"some kind of [sic] tension"* (NY_Producer08), something that catches your attention, and something that makes you stop and think, much like a *"beautiful composition"* (NY_Producer09). Producers wanted the sensory experience with cider to linger, contain lots of

layers, and develop and change as the beverage is consumed. As one cider-maker described, *"Cider is kind of subtle and so to appreciate it you kind of got to not expect it to hit you over the head"* (NY_Producer09), which is to say that when drinking cider, one must pay attention. In this way, most cider producers seek a rich, thought-provoking experience that allows them to actively engage with and reflect on the layers of taste in their experiences; aligning with Hennion's definition of amateurs who continually put their tastes to the test by reflecting on all the tastes that they experience anew (2007). Cider producers grow to appreciate the complexities that cider can offer as they attune their palate to nuances; deciding what is too much, what is just enough, and what is completely lacking. Further, as more and more cider producers view the complexity of traditional-style cider as artistic, beautiful and thought-provoking, this in turn creates a community of cider-producer-*amateurs* who evolve to favor a collective, complex taste (Hennion, 2007; Teil & Hennion, 2018).

> *"there is a [sic] there is an element of, you know, what do you stop and think about it, you know, stop and taste. What are you tasting? You know, rather than just gulping it down. I mean that's the essence of learning flavor right."* (VA_Producer13)

Interestingly, cider-makers were divided in their views on cider tasting like apples: some cider-makers did not want apple-y flavor in cider, saying *"we don't expect wine to taste like grapes"* (VT_Producer20), while other producers did, saying *"wine does not taste like grapes, sure, but when I drink cider I want it to taste like apples"* (VT_Producer19). This discordance in how producers expect cider to taste like or unlike its raw material contrasts expectations of the wine industry wherein *Vitis vinifera* grape breeds are expected to produce wine that does not taste like table grapes, a defect flavor commonly referred to as 'foxy' (Benucci, 2020; Sun et al., 2011).

## Value in a Story

In attempting to describe "good" and "bad" cider in terms of sensory quality, cider producers often derailed into discussion about apple varieties, production processes, and the place from which a cider originated or was made. These artifacts of the apple-to-cider transformation culminate into what we term the "cider story." Many cider-makers made clear their preferences for ciders that have a story: where elements of the apple-to-cider transformation are conveyed with and through a cider product. When asked what he values in a cider, one producer said *"like a cider that's interesting so maybe one that's like a little different, something that I can maybe learn something from is [sic] is an interesting, is a thing that I really like,"* and when asked what he could learn from a cider, he responded: *"I think you know for me it's like I think so ciders that, you know, draw from like a specific region. I think that's really interesting. So, you know, I'm a little unsure as to like what you know terroir in cider really like means, but you know I am curious about like what is the difference between like a dry cider that uses all Virginia apples versus a dry cider that uses all Maine apples, you know, for instance, I mean, I'm interested in single varietals because you can sort of like taste the sort of like, you know uniqueness of one apple versus another. I like interesting processes"* (NY_Producer06). Similarly, when asked what "a cider with a story" tastes like, another producer said *"there's*

*something unique to it. And I don't know that like I, I can taste when someone has used a lot of sulfites. I can taste when something isn't well balanced with the fruit, it just kind of tastes one note, and almost seems like it's clear and metallic. I don't filter anything (.) I like things that are unfiltered, I think that filtering"* (NY_Producer07). Still another cider maker said that *"the story was in the process"* (NY_Producer04), in referring to traditional-style cider; confirming that how a cider product is made translates to the cider story. Altogether, elements of the cider story that producers discussed and closely related to the cider sensory quality included *terroir*, the apples (varietals, how they were grown, the history of different varietals), fermentation and other production methods, and the overall history of cider in America.

### Terroir

Firstly, many producers enjoyed experiencing the taste of place, or *terroir,* in cider, as exemplified by the former quote by NY_Producer06 and others: "*what I love about cider is I, I, I love that it is an opportunity to, in a very like tactile visceral way communicate with customers, like the sort of beauty and uniqueness of the place where those apples are grown"* (NY_Producer01); *"That's why I like cider, it comes from an orchard, whether it's, you know, a single orchard with with terroir overlooking you know a (inaudible) outcrop or, you know, [sic] doesn't matter whether it's a guy in Michigan"* (NY_Producer10). In talking about the *terroir* of cider, many producers emphasized both their desire to learn how cider tastes different when it comes from different places, as well as the need for "traditional" cider-making practices and the need for transparency about cider-making practices in order to allow the taster, whether that be themselves or the consumer, to fully experience *terroir* and understand the origins of the sensations that they experience. These producers advocated for transparency in order to avoid *"bogus insinuations"* (NY_Producer01) about how cider products are made, particularly given that the cider industry currently lacks regulations regarding the cider-making process and the definition of "cider."

These observations of how producers consider production processes in their understandings of *terroir* is consistent with previous discussions on the need to consider human factors of production in determining the authenticity of *terroir* in food and beverage products (Trubek, 2008). As well, transparency in the human elements of cider production (i.e. cider-making process), as well as the natural elements (i.e. geography), is important for the industry to avoid unsubstantiated marketing claims about *terroir* in cider, as has become a topic of concern in the artisan cheese sector (Paxson, 2013, p. 196).

Apples are the raw material used to make cider, and so are a key contributor to the formation of *terroir* in ciders. Some cider-makers specifically valued where apples were sourced from or grown; defining good tasting cider as cider *"grown in a good terroir, which the Hudson Valley does offer"* (NY_Producer03). Uniquely, by asserting that *his* geography of production is inherently "good," NY_Producer03 and other producers with similar beliefs confirm various scholars' assumptions that locating cider incorporates emotional, possessive elements into the *terroir* concept*,* which can allow people to appreciate taste in new ways (Daynes, 2013; Trubek, 2008, p. 12)*.* Other cider producers described their interest in tasting the different flavors that individual cider apple varieties have to offer and how these varietal qualities vary when grown in different regions, overall: *"I think as a cider maker like it's really interesting, right, because then you can see like, okay, there's a [apple] variety I'm familiar with but it's you know, from down the*

*road and so they just treat it differently and they got this really different result."* (NY_Producer09). This reiterates how cider producers simultaneously engage with both regional and human elements of *terroir* by acknowledging the geographical origins of apples and how they are transformed into cider in different ways by different producers (Trubek, 2008). Many cider producers wanted to have a better understanding of apple varietal character, often discussed and elaborated upon in the context of wine as typicity (Ballester et al., 2008; Leriche et al., 2020; Souza Gonzaga et al., 2020; Trubek, 2008). Typicity is a phenomenon wherein sensory characteristics of a product are an extension of geographical and production factors; however, a comprehensive understanding of varietal typicity in ciders is severely limited and inconsistent (Dawson et al., 2019; Littleson et al., 2022; Nicolini et al., 2018; Rosend et al., 2019; Soomro et al., 2022). Recently, *varietal* typicity has been specifically demonstrated to be an important factor in consumer choice for wine, a trend that may have implications for the cider industry as well (Kustos et al., 2019; Perrouty et al., 2006; Souza Gonzaga et al., 2021).

However, not all cider-makers valued *terroir* and varietal typicity in the products that they make and consume. Some producers viewed the lack of varietal-specific expectations as conducive to creative expression with apples without ascribing cider products to a pre-established identity: *"There's so much documented understanding of what different varietals, different growing regions, and different methods of winemaking, what the outcomes are. I feel like there's just a fraction of that in cider and, and the fun thing about that is there's, there's no real kind of cultural stigmatism as to what cider has to be"* (VA_Producer15). As a separate example, one modern-style cider producer placed more emphasis on preferring dry-style ciders and those co-fermented with other fruits over those which expressed the taste of a place (VT_Producer20). In discussing where his modern-style cider fit into the American cider marketplace, another cider producer said, *"You know, why can't something people made still be good regardless of where the fruit comes from?"* (NY_Producer10). In context, this cider maker discussed how good-tasting cider only needed to have balance and an absence of faults, but it did not need to be from a certain place and made with certain types of apples. These diverse preferences suggest a discordance among cider producers in regard to defining cider quality based on extrinsic factors (i.e., *terroir* and varietal typicity).

### Production Elements

Separate from *terroir*, producers spoke at length about how apples and other elements of the cider production process were integral to cider quality overall. Dessert apples were widely believed to make "bland" cider, and cider-specific apples were thought to provide more intense, complex flavors, making for a better cider: *"dessert juice can come out two dimensional, once you ferment it out, it just doesn't. There's nothing. There's nothing to it."* (VA_Producer13), *"thank goodness, there's cider apples and these varieties that have all of these different structures and are super complex"* (VA_Producer12); *"Dessert apples don't really make good cider"* (NY_Producer02). However, some producers who made mostly modern-style cider preferred to use table or dessert apples because their lack of flavor allows for creating more consistent and flavorful cider through the addition of non-apple adjuncts. In this sense, experimentalist approaches to making modern-style cider do not prioritize sensory quality that is an extension of place or apple varieties.

Other elements of the cider production process that producers discussed (in terms of what they make, what they like to consume, and cider sensory quality) included approaches to microbial fermentation, including the use of domesticated or wild microorganisms for fermentation. More purist producers often aimed to use 100% natural or native yeast for their fermentations: *"I actually have a very specific process for culturing wild yeast, where I go out into the orchard, about three days three or four days ahead of whatever we're pressing to the place where we're picking from get the apples, grind them with the skins on and begin a starting fermentation. And then inoculate the tanks with them"* (NY_Producer01). More experimental producers preferred to use different domesticated yeasts in order to explore their potential impacts on flavor: *"I've spent a lot of time just researching and using different yeast. Just, it's supposed to be a more thiol rich for a variety of apples so using like Sauvignon Blanc yeast with like certain enzymatic properties that were like enhance that aroma and add that sort of like pineapple-y character to this"* (VA_Producer11). This producer also emphasized his interest in matching specific apple varieties to specific yeasts with the goal of creating more complicated sensory profiles. Further, some producers noted their use of only one domesticated microorganism across their whole line of ciders so that they could allow the integrity and differences in the raw materials of their cider to shine through: *"we haven't gone that direction in wanting the yeast to leave a specific mark. We want the yeast to disappear, to basically do its job and be done."* (VA_Producer16).

Other examples of cider production methods that contributed to the cider story included letting pulp macerate for 24 hours before pressing the juice (NY_Producer06), backslopping for continually fermenting new batches of cider (NY_Producer04, VT_Producer20), the use of qvevris for fermenting and aging cider underground (VA_Producer12), and the use of applewood that was smoked in the producer's backyard (VA_Producer13). Producers also noted that good cider takes time to produce, allowing flavors to develop: *"you've got alcohol you've got esters, you've got other components to the cider that, [sic] that are immature for a time. Eventually they meld, work with each other to create a more interesting profile. So, we seek to make [sic] make or allow ciders to age to the point where they reach a mature profile where they have mouthfeel where the, [sic] there's a definite beginning, middle and finish to the taste of the cider, the palate"* (NY_Producer03). Producers discussed how time is a trade-off for manipulations on the path to making a good-tasting cider, because the underlying notion is that in order to ferment a cider from start to finish quickly, production methods often require added acids, adjuncts, or sugar (for flavor), or added nutrients, fining agents, and antimicrobial agents (for stabilization; Lea, 2008; Proulx & Nichols, 1980). In contrast, longer production times and nutrient-rich apples can nearly negate the need for such manipulations. These approaches to different methods of production are, subsequently, an extension of cider-makers philosophies and their desires for the end quality and style of their product: *"if I'm making Citizen Unified Press, I can get that from start to finish in 21 days. You know, quick fermentation, run it through a bright tank, put it in a can, out the door it goes. Because, you know, my cider takes [sic] that hasn't even finished fermenting by the time they've got their stuff in a can. And again, it's just a difference in style"* (VT_Producer18). Though cider production can require anywhere from a few days to several weeks, and cider can be aged for upwards of multiple years (Lea, 2008), the sensory quality effects and consumer perception of cider production time and aging are not well-established.

### History

History, of the orchard, of the land that an orchard is on, of the apple varieties, of other ingredients, and of the cidery's equipment, were also mentioned as relevant pieces of the story of the cidery. Producers valued the rich apple-growing histories of the Shenandoah Valley, Hudson Valley, Finger Lakes, and the state of Vermont explicitly: *"we have a huge, huge heritage in this country I mean in Virginia. It is huge. They say that like driving down Shenandoah Valley where 81 is it was like the Napa Valley of the apple world. It was like on all the ridges that it was nothing but, you know, apple orchards, and then there was this huge culture of apple growing and and that's disappearing."* (VA_Producer14). Producers discussed an interest and appreciation for how cider has *"been a popular fruit all the way through American history."* (NY_Producer06); however, producers spoke at length about the unfairness of American cider's inequitable history which exploited the labor of slaves and colonized the lands of indigenous orchards (Abrams & Nowacki, 2008). Two female cider-makers elaborated upon current inequities in the cider industry including limited access to land for females and minorities, and the reliance on immigrant labor in commercial orchard and cider operations; sentiments previously observed in the US and Canadian cider industries (Weiler, 2021). Though these notes highlight uglier stories of the cider industry, they recall discussion regarding diversity, inclusion, and equity in the cider, apple agriculture (Weiler, 2018), and broader alcoholic beverage industries, as has been recently done for the craft brewery and hops industries (Carney, 2022).

It is also relevant to note that cider makers that tended toward the purist end of the cider philosophy spectrum often put more emphasis on wanting to share the history of their land: *"I would really love a big part of the education component to be talking about, like, you know the actual long history of this land and like native people that were here"* (NY_Producer07). Comparatively, more experimental producers often emphasized how cider was historically intended to be the working man's drink: *"cider is supposed to kind of be like a working person's drink like it's, you know, kind of like beer was like, come in from the fields and have a drink. So I think that it should always be approachable"* (VA_Producer11). Historical texts have documented accounts of cider simultaneously being a communal beverage, a working-mans beverage, and a beverage for the upper-class and American presidents (Calhoun, Jr., 2010; Proulx & Nichols, 1980).

Further, producers are in the unique position to explore the history of cider, their land, or their apples (where applicable), and select which artifacts of history they believe worthy of sharing through the products that they make. These sentiments are similar to the ways in which artisan chocolate producers have been documented to look to historic or ancient ways of chocolate-making (Leissle, 2017) as a way to abandon industrial chocolate production. Such practices overall contribute to notions of a cider "renaissance" wherein production methods are evolving away from those of factory-based industrialization (Leissle, 2017; Paxson, 2013, p. 98), and history-oriented ideals are added to this mix, pushing cider as a social unifier (Guptill et al., 2017, p. 22).

### Creating the Value

Lastly, producers emphasized how the story appeals to consumers and creates connection between the producers, the consumers, and a place: *"what it can provide is a*

*connection to a cidery, where people can go they can come here and they can learn how we make cider and they can trust that we know what we're doing and we've been doing it 30 years and, and have that connection to the brand, and they can have a connection to, to a specific orchard if you're an orchard-based cidery."* (VT_Producer17). Appropriately, one producer said *"I like to always have a story behind my cider, like why I did it or whatever. Okay, I just feel it kind of sells it better too"* (NY_Producer02), highlighting how production-oriented information not only creates a story and can tell the tale of *terroir,* but also adds value in the eyes of consumers. These observations align with how *terroir* can be a socially and economically embedded in communities (Trubek, 2008), and how consumer values are reordering to desire connectedness and a story about where their food comes from and how it is made (Labelle, 2004; Myles, 2020; Paxson, 2013).

Consumers are not the only group that values production and place-based information for cider products. Producers act as *amateurs* who use production-related information to guide their sensory experiences, becoming attuned to not only the sensations of their mouths, but also the reducible causes of those sensations (Hennion, 2007, p. 101). In this sense, the backstory of production is capable of influencing how a cider product is experienced (or "tasted"), and the continual tasting of cider products with a backstory serves to train the cider producer to develop beliefs about those backstories. Yet, the power of reducible causes of taste sensations need not be over-exaggerated for production, geography, and varietal typicity are only guideposts – the act of tasting is still entirely in "what is happening" (Hennion, 2007, p. 99). In other words, even cider products that have a great story still need to taste "good," and so producers attempt to remain focused on the act of tasting itself.

> *"If it's a cider that's made you know in a very natural process with great intention, but tastes like socks, then it's not a good cider, even if you had good intention behind it"* (VA_Producer15)
>
> *"If it doesn't taste good like no one gets [sic] no one's going to give a shit like if it's gross"* (NY_Producer07)
>
> *"Where does cider begin and end, you know, it's like, this is you know, history in a glass. This is terroir, this is, you know, every single this apple, this concoction, is telling a story, it's got this huge, rich history. So the more people know about that, I think it adds to a, you know, a romantic element of the experience"* (VA_Producer12)

In addition, extrinsic elements of the 'cider story' seem to suggest that cider is an *unfinished commodity* similar to artisan cheese, described by Heather Paxson (2013). The backstory of how cider is made or where it comes from both adds to the sensory experience and frames the product as an intentionally crafted, specialized result of a place and process. According to Paxson (2013), artisan cheese producers often emphasize select elements of the production story to showcase how natural environmental conditions and empirical craftsmanship lend to the unique finished quality of an artisan cheese product compared to a product made via "assembly line production" (Paxson, 2013, p. 14). Cider producers engage in similar behaviors,

exemplified by their discussions of how time and aging are markers of improved sensory quality and how elements of place can spawn unique, thought-provoking sensory features. By unveiling the backstory of cider products, including information about terroir, production, varietals, or history, cider producers expose the value-systems that inspired them in their cider-making and generate moral value for themselves and their commodities.

## Cider Economics

When asking cider-makers how cider should be valued, cider-makers spoke at length about how a cider's value was a culmination of many different factors including extrinsic product factors (i.e., packaging), how the cider was made, what apples were used in the cider, and other supply chain factors. Cider producers had contrasting and complex views about the current cider marketplace in terms of what was simultaneously ethical, profitable, and personally satisfying. In this section, we contextualize these perspectives on cider economics and the agricultural economics associated with apples with a rich discussion on how these findings relate to other cider industry research and broader socioeconomic theories.

### Packaging

With discussing how cider should be valued, ample discussion arose regarding cider packaging. For producers whose goal was to make money and grow, bottling cider was not a viable option: *"Bottles are a dead format if you want to move any sort of volume"* (NY_Producer04). Other producers noted how bottled cider was only sellable in wine producing regions, where bottled beverages are more commonplace to begin with: *"Finger Lakes you only can sell them there because of all the wineries, if they didn't have those wineries there they wouldn't sell their 750 milliliter bottles"* (NY_Producer02). Such ideas are reminiscent of various scholars' discussions about cultural *terroir* and theories of economic embeddedness wherein markets operate with cultural, social constraints (Barham, 2003; Lahne & Trubek, 2014; Paxson, 2013). Comparatively, cans are cheap for producers to use and get more people drinking cider, though they can also feel cheap: *"for me personally, it is almost impossible to shake the feeling that what I'm drinking in a can is [sic] should be lower in alcohol, like thirst quenching and fairly inexpensive."* (NY_Producer01). One producer emphasized how canning cider allows it to be viewed and valued similarly to that of beer, minimizing cider's value when it should be worth much more considering how much time, effort, and unpredictability goes into cider's raw material: *"We're a victim of our own history, in that we've sold cider like beer"* (VT_Producer17).

### Commodifying Production

Producers unanimously agreed that consumers overall should pay more for cider than they are currently paying because apples *"cost more than water"* (VT_Producer18). Indeed, apples are a biennial, unpredictable crop requiring extensive attention and financial resources to grow year round (Becot et al., 2016; Futrell, 2017; Merwin, 2015; Peck & Knickerbocker, 2018). This quote means to say that cider should always be more expensive than other comparable alcoholic beverages that use water as a primary ingredient (i.e., beer). There is also an inherent expectation that cider should be made with a level of care, intentionality, ingredients, and process that do justice to the cost, effort, and resources required to grow apples. Unlike water,

apples are not freely obtained; and so the way that apples are used and the types of apples that are used in cider-making heavily influences how cider is valued.

Though cider should "cost more" in general, cider producers broadly disagreed on exactly how much cider should cost. Most producers believed that cider should cost an amount that depends on how it is made. For example, a cider that takes longer to produce or utilizes rare apples that were grown ethically, sustainably, or with some extra level of care, should cost more. Cider that is made from concentrate and in a quick amount of time should be relatively inexpensive. Traditional style ciders are often those that constitute the former – taking longer to produce and made from mostly rare, cider-specific apples that can be inconsistent across growing seasons: *"I think America probably went from the most diverse apple growing place in the world to the least. And, and that really limits what you can produce. If all you got at your disposal is galas, red delicious, and Fuji and whatever, you know, and maybe a Winesap, there may be a Goldrush, that limits what you can do in cider. Yeah, that's important to talk about"* (VA_Producer15); *"we don't have a great enough supply of tannic apples to satisfy all the cider makers. They're rather expensive compared to just dessert apple juice"* (NY_Producer03). Producers also discussed how consumers are often not aware of cider-specific apple varieties or traditional production processes, contributing to a limited market potential for traditional styles of cider.

Even still, of those producers who made traditional styles of cider, some charged the true amount that they believed their product to be worth based on how it was made while others priced their traditionally-made cider slightly lower than they believed it to be worth. Producers who priced their products lower than they believed their products to be worth did so primarily because the profits of other cider products could balance out the losses on products made with more expensive materials or longer amounts of time. Secondarily, pricing cider lower was relevant for maintaining approachability pertinent to cider's history as the "working person's beverage": *"I like where we've managed to price the Farmhouse Dry. I'd like it to stay, actually it's been the same price, the kegs have been the same price the whole time I've been at Potter's. I'm sure we could have stood to increase that. But I think [sic] just does so much good for our brand in the industry overall. And like cider is supposed to kind of be like a working person's drink"* (VA_Producer11). This quote in particular highlights this producer's passion for cider being an affordable social unifier, as previously discussed.

"*The cost of making [sic] it is so dramatically different based on how you're making it"* (NY_Producer09)

*"There are various economies that bear on the price of the cider I mean, if you're using dessert culls from the West Coast, they're going to be dirt cheap… doesn't mean the cider can't be good. But if you take other shortcuts in the fermentation and production processes that compromise what the product could be and just settle for that, then it's not as good and you shouldn't get as much money for it anyway."* (NY_Producer03)

*"I think that there are a lot of craft centric cideries now that are starting to prove to the consumer that there's cider out there worth more money than [sic] than the average or the original ciders that were out"* (VT_Producer20)

*"I think, unfortunately, the market tells us what we can sell our cider for, rather than us saying this just give everybody a fair wage. Let's just pay the farmers, what they ought to be making for their apples and work backwards to, to, what they'll pay at the price. I haven't seen anyone be successful doing that yet."* (VT_Producer17)

*"I think all of the cideries that are doing like what we're doing, orchard ciders, we're way under priced. Is there a market for for paying, you know, a more premium price? Not at this moment."* (VA_Producer12)

These sentiments are a continuation of how the cider story is value-adding, but they also exemplify the commodification of production ethics and labor (Paxson, 2013). As well, they highlight the power that producers have to unveil the politics (and economics) of cider production to consumers, a facet of Marxist theory (D. Goodman & DuPuis, 2002). As producers instill their values related to agriculture and production into their products, the beverage itself becomes defetishized but hard work, sustainability, and other production elements become fetishized in trade. To be a cider-maker is not simply the pursuit of business success nor craftsmanship; it's a moral livelihood to use apples in a way that maintains and increases their value rather than reducing it, and to convey that to consumers – to foster an economic culture that values cider based on *all* of the systems that went into it rather than its utility value alone. By producers sharing their stories of how cider is made and asking for a higher price in return, they are conveying their values about agriculture, who they are, how they make cider, where they make cider, and why: *"For me, because like I said it's coming out of the land that I'm at, and it tells a story of where I am and who I am"* (NY_Producer07). Commodifying aspects of production has been discussed as a potential detriment in other food systems, such as those that encompass animal welfare and "free-range" eggs (M. Carolan, 2021, p. 122). However, the long term implications of production commodification is not well understood, particularly in a young and growing industry such as the American cider industry which currently struggles to articulate definitions of quality.

*"You know it would be this notion to understand how it's made and what goes into it, but, you know, first we have to grow the tree. And then those trees have to start producing fruit, then that fruit has to grow an entire season. And then we have to get it through the entire season with nothing bad happening to it. And we have to pick it, and then we have to press it, and then it is all the labor that goes"* (VT_Producer18).

*"I think that there are ways to try and like market yourself in different ways so people see you as a higher value product, you know, and that for me also is part of telling the story of like*

*being direct with people like it says how long it takes, these are all the things that I'm doing… I know it makes people more inclined to pay for it."* (NY_Producer07).

### Sensory-Economic Tensions

Cider producers also toil with the economic tension of whether or not to produce a cider that meets their sensory desires. Though most cider producers preferred the complexity and nuance of traditional style cider, some explicitly choose not to make traditional cider because it does not *"pay the bills"* (VA_Producer12). By this, producers emphasized how cider-specific apples contribute complex sensory qualities in traditional style cider, but that most consumers do not appreciate these sensory qualities (in addition to not knowing about cider-specific apples to begin with), therefore adding to the limited the market potential of traditional products. Yet, this means that there are very clearly cider producers who make products that they do not personally prefer: which begs the question, how long can someone make something that they personally do not favor? At what point will a producer either abandon the weight of needing to satisfy consumers or abandon their career of making something that they do not find fully satisfying? For example, one interviewed cider-maker discussed his desire to return to his roots in traditional-cider-making and establish a cidery where he can have a "direct to consumer outlet" for making and selling more "natural cider" (NY_Producer04). We suggest that producers' preferences of what type of cider to make (and consume) are guided by their own sensory preferences and values, but that the economic and personal tensions acting upon producers are also heavily influential on the products they make and the values that they perpetuate to consumers.

It is relevant to emphasize that, in talking about apple agriculture and cider economics, some purist-leaning cider producers were not reliant on their cidery for their full income: a premise that exemplifies the forces of economic tensions. Cider producers whose livelihoods are supported by other family members or other sources have businesses that have a lower economic threshold of viability (Paxson, 2013), so they may be less inclined to cater to the preferences of consumers in the marketplace. As one cider-maker put it, *"I make my little cider over here and if you want it, you come get it"* to describe how he did not care what consumers wanted. Yet this same producer also said, *"our livelihood isn't tied to me. I'll be honest about that. For some people it is… unlike a lot of my peers, I'm not trying to scratch out a living doing this"* (VT_Producer18). As with artisan cheese, most small and medium size cider producers are not getting rich off of the labors of cider-making; rather, "they are getting by – or relying on wealth generated through other means" (Paxson, 2013, p. 83) because of the economic confines of apple agriculture. Producers looking to escape this cycle and make a profitable cidery business may, therefore, struggle to balance what they personally want to drink and make versus what they want to sell, which is indicative of Stephen Gudeman's economic tension wherein there are two ways of "making material life – for the self and for others" (Gudeman, 2008, p. 14).

### Economies of Scale

Lastly, cider-makers engaged in discussion related to scale of cider production and locality. Many cider producers indicated their desire and preference for *"not getting too big"*

(NY_Producer06) or an interest in keeping things small: *"We have no interest in that [producing volume] at all. We get approached by distributors we've turned them all down. We just don't want to be that company. We're not interested in making 100,000, or a million gallons of cider"* (NY_Producer02). Apples were heavily influential on the scale at which a cider-maker could produce cider because cider-specific apples are so rare and limited (Miles et al., 2020; Ostrom et al., 2022); therefore, as cider-makers emphasized that cider made from cider-specific apples is not producible at a large scale. Thus, for cider producers who approach the cidery business model to maximize their volume and profits, using cider-specific apples is not viable.

Preferences for local fruit continue the theme of scale: only so many apples can come from local sources or be grown in a certain area. Further, there is no concrete definition of "local" cider – is "local" defined by where the apples are from, where the cider is made, where the cider is sold, or all of these things? Farris et al. (2019) has ascribed 'localness' to the state in which a cidery is located, which avoids discussing the geographical origins of apples used to make a cider. Nonetheless, producers varied in their preferences for "local." For producers focused on efficiency and profits, local was not a priority: *"For it to come from local sources or not doesn't really matter to me too much"* (NY_Producer04). For some producers, local meant that cider fruit had to come from the US, at the least, or from the region or state: *"we've been sourcing our apples, almost exclusively from southwest Virginia, sometimes as local as a tree about a block from here, a few trees about a block from here sometimes"* (VA_Producer13). At best, the cider-maker was also the apple-grower, allowing the whole cider production chain to be centralized in one, often rural, place or community. For producers who aim to source local products and stay small in the size and volume of their production, the goal is less about making money and more about creating a product that expresses the elements of an environment or the craftsmanship of an artisan. In turn, these such regional and hand-crafted products facilitate more community connectedness: *"most cidermakers are going to be small and niche, and they're going to have an opportunity to connect with their consumers"* (VT_Producer17). Such economies of scale and sentiment are comparable to those described in artisan cheesemaking (Paxson, 2013), where the artisan mode of cheese production is motivated by craftsmanship, environmental sustainability, animal welfare, family tradition, community culture, and a host of other forces.

> *"As long as people are drinking cider, that's what makes me happy and especially if it's coming from local orchards and whether it's dessert fruit or specialty fruit. There's a ton of room, ton of growth and ton of opportunity."* (NY_Producer10)
>
> *"I'll echo a thing that our friend Andy Brennan, who I mentioned earlier, said he thinks there should be a renaissance of cider making at the small scale level. I think that that presents the most promise for apple growers in the first place, because we are first an apple grower so the… interest in cider making has brought to bear for these older apples is [sic] is welcomed because we've grown them. They've been hard to sell in the past"* (NY_Producer03)

## The Drinking Occasion

In discussing cider, some producers made note of how their preferences change depending on the drinking occasion. Many cider-makers drew connections between the drinking occasion and their sensory preferences: *"I like to think there's a different cider for every occasion, so [sic] sort of depends on what it is I'm eating, or what I'm doing that day, you know. If I'm out on my kayaks maybe light American style cider will be the thing to do. If I'm having, you know, you know, a cold winter dinner with, you know, pork roast or something, I'll try something a little bit more tannic"* (NY_Producer10). Producers expressed how light, refreshing cider better suits casual drinking occasions, whereas complex cider better suits reflective, meal-oriented drinking occasions. Further, the light and refreshing cider of casual occasions is also often packaged in a can, making such a product more affordable and approachable for commonplace consumption occasions. The complex, tannic cider that is better suited for reflective, intimate, meal-oriented or special occasions is often packaged in bottled cider, exemplifying how both cider sensory quality, cider packaging, and the drinking occasion are three factors which seem to define the cider-drinking occasion according to cider-makers. These sentiments closely parallel those of cider consumers in the Northeast and Mid-Atlantic (see *Chapter 4*) and research of Virginia cider consumers who ascribed different styles of packaging to different drinking occasions (Kessinger et al., 2020).

Some producers discussed how the occasion influences the desire for background information about a cider product or cidery. Though there is value in a story, and many producers do enjoy learning something about cider (i.e., cognitive, informational) and from cider (i.e., reflective, sensory), the story is only welcome at certain times and places. Therefore, cider producers must find a balance between sharing product information that is both value-adding and interesting, but in a way that is appropriate for the intended consumption occasion. Though product information can be valuable by providing knowledge that fosters connectedness in the food system, excessive information given at inopportune times can be pretentious, cause specific production-related terms to become commodified, and can forge cultural divisions amongst consumers (Bourdieu, 1984; Labelle, 2004). Thus, a cider marketplace that has different products and different ways of disseminating product information to suit different drinking occasions is powerful in giving consumers and producers agency over their food choices and connectedness to the broader food ecosystem.

> *"The main goal here is [sic] like sort of to connect people with not just cider but like the land itself, you know, where cider comes from. And sometimes people just, that's not what they're looking for, so we're not going to like, shove it down their throat. You know if people are coming to hang out and hear music, and have dinner. We don't need to talk about it."* (NY_Producer08)

## Limitations

The present study aimed to holistically explore cider producers' preferences for cider and the cider-drinking experience, through a lens of both production and consumption, in a representative sample of American cider producers in the Northeast and Mid-Atlantic US.

However, this research has important limitations. The studied sample of cider producers may not accurately represent the perspectives of all cider producers across the Northeast and Mid-Atlantic US. Cider producers may have values, preferences, or beliefs that sample from both purist and experimentalist perspectives, or they may have beliefs that are completely different from those conveyed in the present study. However, the present research design is underpinned by a critical realist ontology and contextualist epistemology which assert that all of the viewpoints shared in this study are real, true, and valid for the specific participants involved in the study, and because of the environmental context in which the research was conducted (Braun & Clarke, 2013; Tebes, 2005). The findings presented here are unique, and may or may not be applicable to other cider-makers and the broader US cider industry.

As well, the researchers acknowledge their fundamental role in conducting, framing, and analyzing the phenomenological results presented here. The first author (MDC) was the lead researcher on this project, serving as the moderator for all interview sessions and the primary coder during reflexive thematic analysis. Both the first and last author are trained sensory scientists, with other authors representing backgrounds in economics, enology, and microbial ecology.

## *Conclusion*

American cider is an increasingly popular beverage led by regional cider producers and small- and medium-size apple growers who contribute to local and rural economies. Alongside the cider industry's continued national and regional growth, researchers have given considerable attention to understanding cider production practices, cider sensory quality, cider chemistry, consumer preferences for cider, and supply chain dynamics that affect cider producers. However, a holistic account of how cider producers view and value the products that they make has not been described in research. Through the use of qualitative interviews with professional cider-makers, this research aimed to explore producers' preferences of cider and their perceptions of cider quality and the cider-drinking experience. This research used a select group of American cider producers from three leading cider-producing states, New York, Vermont, and Virginia, to take a "snap-shot" of producer preferences and perspectives in the Northeast and Mid-Atlantic US cider community. By exploring the multiple shared and simultaneously unique realities and backgrounds of cider producers in contextual settings, results of this research were found to support previous research related to the cider production supply chain. As well, this report offers new insights that bridge the gap between cider consumption and production by showcasing how producers value cider as inherently knowledgeable consumers themselves.

Altogether, these findings showcase how cider producers approach cider-making and drinking through a wide spectrum of diverse philosophies regarding how apples should be grown and used in cider, how cider should be made, and the end goal of the cidery business. Cider producers' perception of overall quality in cider was heavily informed by a product's sensory character, where many producers preferred balanced flavors and mouthfeels. As well, many producers pay close attention to how cider production processes carry through into the final sensory quality of the product. For some producers, experiencing and showcasing *terroir* in the products they taste and make respectively make was fundamental to the cider experience,

while other producers were motivated to use apple juice as a vessel for experimentation. Producers also offered diverse perspectives on how the history of American cider in the US should be discussed and recognized within the broader alcoholic beverage industry and with consumers. Cider producers' beliefs were heavily influenced by their own economic position, ethics, and access to and approach to using agricultural resources. Lastly, the consumption occasion guided many producers' beliefs and values related to cider quality, which closely aligns with the perspectives of consumers and suggests that the cider industry can be successful as a diverse marketplace with products that appeal to a variety of drinking occasions.

Results of this research support the growing American cider industry by highlighting ways in which producers value cider as they continually make new products that are inspired by evolving business and personal goals. Industry stakeholders may be able to leverage these findings to generate new insights as to how the cider industry can be expected to grow and what cider producers need in order to grow the success of their businesses. This research also presents evidence of the dichotomy between traditional and experimentalist approaches to cider making, which may have far-reaching implications for the growing cider industry. As well, we present evidence of the need for industry stakeholders to drive education efforts for communicating and differentiating cider products based on varying quality parameters that may include but are not limited to production processes, the intended drinking occasion, and sensory attributes.

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# *Supplementary Material*

## Supplementary Material I

Producer Questioning Route

**Introduction**

Thanks for meeting with me today to talk about cider and what you do! Obviously, we are going to talk a lot about cider and what you think cider is and should be - remember, nothing is off-limits.

**Opening Questions**

So, to start things off, tell me about yourself and your cidery.

How did you get into cider-making?

**Transition Questions**

What was the last memorable cider that you had?

What is one of the best ciders that you've ever had?

**Key Questions**

What qualities do you pay attention to when drinking cider?

Which of these are the most important to you? Least important?

In your opinion, what separates a good cider from a bad cider?

What parts of the cider-making process do you feel have the biggest impact on your cider?

What parts of the process do you feel like you struggle to control or don't understand?

How does that come out in your cider?

What about cider do you want consumers to know about or appreciate?

How do you feel about flavored ciders? Like those that have fruits in them (like raspberries, orange, etc), hops, maybe barrel aging, etc.?

What do you think consumers should pay for cider? What goes into this decision?

Cider-making has strong roots in colonial America, which avoids slave labor and the original history of Native American agriculture in the Northeast. How do you think cider-making and the cider industry can pay homage to this history?

How do you think cider can be a more *inclusive* beverage?

**Closing Questions**

Any other thoughts you have about cider and the cider drinking experience? What you like and what you think it should be?

# Chapter 6 – Cider catalog: Text mining and biterm topic modeling to explore cider descriptions from the Northeast and Mid-Atlantic United States


## *Abstract*

Exploring topics of communication is an increasingly relevant subject within food and beverage research that can provide insight as to how products are marketed both effectively and ineffectively. The hard cider industry, a sector of the alcoholic beverage industry, is increasing in popularity in the Northeast and Mid-Atlantic United States but restrained by unclear communication among industry stakeholders and consumers. This study aimed to explore the use of frequency-based text mining and biterm topic modeling (BTM) as tools for analyzing how cider products are communicated and marketed on cider-producer websites for products made in Virginia, Vermont, and New York. Text mining, including term frequency and BTM have been previously used for small corpora of text data to explore topics and patterns of terms. The present dataset comprised website descriptions of cider products collected from cider-producer websites and processed based on concurrent research in the US cider industry. Results of the research suggest that cider product information on website platforms most often communicates food-pairing, production, and sensory quality information. This research also reveals consistent differences in how cider products made in different states are communicated differently, as well as tangible areas of improvement for cider marketing and communication. Though this research is heavily limited by data pre-processing decisions on behalf of the researchers, findings strongly demonstrate the efficiency and potential of text mining tools for understanding food and beverage product descriptions.


## *Introduction*

Research into the language of food incorporates various scientific disciplines, including but not limited to linguistics and anthropology (Jurafsky, 2014; Riley & Paugh, 2018b), to explore how food is communicated and valued amongst producers, consumers, and other actors in the food system. In the sensory evaluation field specifically, understanding language and communication is important for understanding food product experiences and perceptions – particularly those which drive repeat consumption and purchasing.

The process of procuring and eating is one of multisensory perception (Lawless & Heymann, 2010b; Riley & Paugh, 2018a) that is heavily influenced by environmental context (Betancur et al., 2020; Lahne et al., 2014; Lawless & Heymann, 2010a; Meiselman, 2019; Stelick & Dando, 2018). Context in the sensory experience can include but is not limited to music playing in the background, visual surroundings in the consumption environment, and information about a product that is being consumed, whether that information is on a package or online platform. In the case of the latter, text-based communication is a pertinent type of context in sensory experiences that can influence expectations about how a product might be or is perceived. For example, information about grape varieties and growing regions have associated

typicality that facilitates cognitive associations and expectations relevant to the sensory experience (Sáenz-Navajas & Jeffery, 2021; Spence, 2020a; Thomas & Pickering, 2003). Researchers are specifically keen to investigate *sensory-relevant* language that is used to describe products to get a broader understanding of how sensory quality is communicated both post- and pre-consumption, but this is not without its challenges (L. Hamilton, 2022).

Qualitative research methods have been most commonly utilized to explore the language and communication of food. These methods can include content analysis (Weber, 1990; Krippendorff, 2019), document analysis (Bowen, 2009), and reflexive thematic analysis (Braun and Clarke, 2006; 2013) which can involve identifying overarching, consistent themes or topics across textual and visual data. Researchers have previously used these methods and extensions of these methods to explore wine blogs (Beninger et al., 2014; Doyle et al., 2012), cookbooks (Parys, 2013), marketing messages (Vasiljevic et al., 2018), and even written responses of consumers' perceptions of processed foods (Sadler et al., 2022). However, the use of qualitative methods for language analysis can be time intensive and limited by researcher bias (Braun & Clarke, 2013; Creswell & Poth, 2018; Peschel et al., 2019), thus presenting the need for research methods that can quickly and effectively investigate how food is discussed.

In contrast to qualitative research methods for exploring food language and food sensory experiences, quantitative methods of language processing can make language analysis more accessible by allowing researchers or companies to quickly process and analyze text (Peschel et al., 2019; Tao et al., 2020). Quantitative language processing for the purposes of sensory and consumer studies can take various forms (Jurafsky et al., 2014; Souza Gonzaga et al., 2020; Tian et al., 2021; Yoo et al., 2023). Natural Language Processing (NLP) is a computerized method of quantitative language processing that involves developing and training a statistical model to process unstructured text, or language that comes in different formats (i.e., from websites, emails, books, etc.). An overview of NLP and its application in the sensory science field can be found in L. Hamilton (2022).

Within NLP is a branch of text analysis called topic modeling, which aims to discover word associations – which can be done based on how often terms occur together, based on semantic similarity (i.e., trees, orchard, apples, apple seeds), or based on the two approaches combined. These text mining processes can allow researchers to quickly investigate themes and topics within text-based data. Latent Dirichlet allocation (LDA) is a commonly used topic-modeling methodology that uses the co-occurrences of words to understand their semantic similarity (Blei et al., 2003; Blei & Lafferty, 2009; Silge & Robinson, 2017). LDA is best suited for very large overall sets of data that are composed of large individual documents (An, 2022; Silge & Robinson, 2017; Vidal et al., 2022).

Recently, Cheng et al. (2014) proposed an alternative to LDA that is better suited for investigating topics in data sets with shorter units of text, such as websites and tweets. This approach to explore topics within short texts is called Biterm Topic Modeling (BTM) and overcomes the problem of data sparsity by focusing on co-occurrences of biterms, or pairs of words, across the whole data corpus (Cheng et al., 2014; Vidal et al., 2022). This approach to exploring topics within a language corpus is called biterm topic modeling (BTM; Cheng et al. 2014; Vidal et al. 2022). BTM has been useful in exploring topics related to consumer perceptions of vertical farming (Vidal et al. 2022) and turmeric (Feldmeyer and Johnson, 2022),

and thus it may be invaluable for exploring *sensory*-relevant language and other information that can potentially influence the sensory experience.

In seeking to understand the language around food and the context around sensory experiences, we emphasize that much research has focused on consumer-based data sets, such as blogs (Beninger et al., 2014), product reviews (L. M. Hamilton & Lahne, 2020), and open-ended responses (Danner & Menapace, 2020; Spinelli et al., 2017; ten Kleij & Musters, 2003). However, few text assessments have been conducted with producer-generated language. Food and beverage producers, and other stakeholders or retailers, add value to products by conveying information about how their products are made and where they are from (Lahne & Trubek, 2014; Paxson, 2013), whether that information is conveyed verbally or in written form. Text-based product information that producers use on their packaging or websites contributes to the context around food and beverages that consumers engage with prior to, during, and after their sensory experience (Bernard & Liu, 2017; Betancur et al., 2020; Kessinger et al., 2020; L. Lee et al., 2006; W. J. Lee et al., 2013).

## Cider

Cider is an alcoholic beverage made from fermented apple juice that is growing in popularity worldwide. In the United States (US), revenue from the cider industry has grown significantly over the past 10 years (Jacobsen, 2022; Peck & Knickerbocker, 2018; Wood, 2022). Smith et al. (2022) and Yenneral et al. (2022) have all documented various consumer preferences related to cider and the cider sensory experience. These researchers emphasize that information about sensory quality explicitly, as well as elements of sustainability, apple varieties, product origins, and other ethical values can make relevant contributions to consumers' affective and cognitive sensory experiences, further supporting evidence of the sensory experience being contextual (Betancur et al., 2020; Charters & Pettigrew, 2007; Kessinger et al., 2020; Lahne & Trubek, 2014).

The American Cider Association (ACA) and other researchers have cited inconsistent and unclear marketing and sensory language as barriers to growth in the current American cider industry (Demmon, 2019; Fabien-Ouellet & Conner, 2018; McGrath, 2019; Ostrom et al., 2022). Ostrom et al. (2022) describe cider producers' need for marketing support that increases consumer awareness of place-based qualities and cider-specific apples, echoing the research of Fabien-Ouellet & Conner (2018). Currently, style guidelines are a common tool for communicating cider quality in the US cider industry, with the two dominating styles being "modern" and "traditional." Ciders are also beginning to be described in terms of the explicit apple varieties that they contain, such as a "single varietal cider" made with only Newtown Pippin apples. Yet, there is little social or cultural consensus on how cider quality can or should be described, particularly related to clear and meaningful sensory communication. Therefore, the present research intends to explore how cider producers currently communicate and market cider products in order to gain a better understanding of how descriptive communication can be improved to best support the growing US cider industry.

### Objectives

The present study aimed to explore the language used by cider producers and marketers to explain their product(s) to consumers. We apply two complementary and easily accessible text-analysis workflows to this problem: so-called “tidy-text” analysis (Silge & Robinson, 2017) and biterm topic modeling (Cheng et al., 2014; Yan et al., 2013). We selected these methods because, while they are simple and accessible, they can provide broad insight into the topics used to communicate cider products on cider websites, from Virginia, Vermont, and New York. These three states were selected because they are leading cider-producing states in the Northeast and Mid-Atlantic US (West, 2018). A secondary aim of this study will be to report on the effectiveness of the “tidy-text” approach and BTM in conjunction for small-scale, quick speech and language processing projects.

## *Materials and Methods*

### Data Collection

Data collection took place from August-December 2020. To determine which cideries to include in the dataset, researchers searched for all cider producers described by *Locator* (2022) and West (2018) to operate in Virginia, Vermont, and New York. After compiling this initial list of cider producers, researchers searched each producer identity or cidery for a website. Cider producers or cideries that did not have an official website with information about their products were excluded from the dataset. From each cidery website, all individual cider product names were extracted along with all product descriptions on the cidery website. All text was directly copied from the cidery website into the dataset. If no information was provided across the website for an individual cider product, then the website description factor was set to “NA.”

Using all information provided on the cidery websites, including individual product descriptions, other product attributes were extracted including: ‘Alcohol-By-Volume (ABV),’ ‘Packaging Format,’ ‘Flavored,’ ‘Single v. Blend’ (referring to the use of one or multiple different apple varieties), and ‘Apple Varieties.’ When listed on the cider website, ‘ABV’ was extracted for every individual cider product. If a product did not have an explicitly stated ABV, the product factor was set to “NA.” ‘Packaging Format’ was made as a factor column to indicate the packaging format for every individual cider product. If the packaging format was not available from any information provided on the website, the factor value was set to “NA”. If an individual cider product came in multiple packaging formats, then the factor value was set to “multiple.” The factor column ‘Flavored’ was set as “Yes” if a product description explicitly indicated that the cider was flavored with non-apple adjuncts. If the product description was clear that no adjuncts were used for flavoring or if flavoring could not be clearly inferred from the product description, then the factor was set as “NA”. ‘Single v. Blend varietal’ was made as a factor column to indicate whether a cider is made with only one type of apple versus a blend of different apples, which is common practice in cider-making (Lea, 2008; Proulx & Nichols, 1980). If a cider product was explicitly described to be made with one apple variety, the ‘Single v. Blend’ factor column was set as “Single” and the ‘Apple Varieties’ factor column contained the explicitly mentioned apple variety. If a cider product was explicitly described to be made from a

blend of different apples, then the appropriate factor column was set as “Blend” and all apple varieties were extracted and recorded in the ‘Apple Varieties’ factor column. If the blend of apple varieties was not explicitly stated, then the ‘Apple Varieties’ factor column was set as “NA”. If a product’s description had no mention of apple varieties or blending format, the “Single v. Blend” column was set as “NA”. In some instances, where apple varieties were of an unknown identity described as “wild-foraged,” “heirloom apples,” “rare,” or of similar language, the ‘Single v. Blend’ factor was recorded as “Blend” and the ‘Apple Varieties’ factor was recorded as “undesignated.”

All data was manually retrieved (i.e., copy and paste) by first and second authors and stored in an electronic spreadsheet. The column headers of all data retrieved for the project are indicated in *Table 1* for clarification. In total, 1115 cider products, their website descriptions, and all previously described information was extracted from 124 cidery and cider producer websites, from across Virginia, Vermont, and New York.

## Data Analysis

All data was analyzed using R software version 4.1.2 (R Core Team, 2018) and was closely adapted from procedures outlined in Silge & Robinson (2017), Wickham (2014), Cheng et al. (2014), and Yan et al. (2013). Based on procedures outlined for data processing by Silge & Robinson, (2017), apple varieties described for each cider product were tokenized and varietal frequencies were explored across state, apple variety use, and packaging format. Website descriptions were filtered to remove English stop words, using the stop word list provided in the stopwords package for R. Website descriptions were tokenized and term frequency-inverse document frequency (tf-idf) was run across state, apple variety use, and packaging. Term frequency refers to the number of times individual terms occur in a document. Term frequency-inverse document frequency is a method of showcasing how important a given term is to a given document by minimizing words that appear across multiple documents and emphasizing words that appear in select documents (Silge & Robinson, 2017).

Biterm Topic Modeling (BTM) was carried out following Yan et al. (2013) and Wijffels et al. (2021), and inspired by the work of Vidal et al. (2022). BTM was selected to accommodate the smaller corpus of data as well as to accommodate the relatively small units of unstructured text (i.e., website descriptions) in the present study. The methods of BTM utilized in the present study involved assessing biterm co-occurrences within individual product descriptions (also known as “skipgrams”) in the entire cider catalog corpus, and within reviews from each of the three states individually, removing stop words, and filtering parts of speech to only include nouns, adjectives, and verbs in the topic models.

In order to train a BTM, specifying three hyper-parameters is necessary: the number of topics (K), alpha, and beta. The latter values, alpha and beta, control topic density and were set to recommended values (alpha = 50/K, beta = 0.01) based on Cheng et al. (2014). The BTM is trained to assume an underlying number of topics across a corpus, and the model will find distribution trends of words across these topics. Though there is no standard, pre-established way to determine the optimal number of topics for any given corpus, researchers have recommended training a biterm topic modeling with different numbers of topics in order to discover which number best suites the data by yielding a higher average topic coherence based on subjective evaluations (Cheng et al., 2014; Vidal et al., 2022). The present data set was

trained using multiple biterm topic models for K (K = 1, 2, 3, 5, 7, 9) for the whole corpus of biterms, and two biterm topic models for K (K= 5, 7) for the corpus of biterms separated across the three states. First and last author read the words associated with each topic and qualitatively decided on the number of topics which best fit the data. Researchers performed this analysis together. Topics were deemed coherent when the researchers unanimously agreed that a clear topic or theme could be identified from the clusters with minimal repetition of non-related terms across topics. All topic models were visualized using cluster graphs following procedures described by Vidal et al. (2022) and (Wijffels et al., 2021).

# *Results*

The present data set, which we refer to as the “Cider Catalog” moving forward, comprises 1115 cider products, representing 15 cider producers from Vermont, 32 cider producers from Virginia, and 77 producers from New York. In the following section, we describe results of our text mining closely adapted from methods described by Silge & Robinson (2017) and Feldmeyer & Johnson (2022), Vidal et al. (2022), and Yan et al. (2013), and we visualize trends across the data set according to factors including apple varieties, packaging, and state.

## Term Frequency Methods

### Apple Varieties

To explore the use of named and unnamed apple varieties in ciders across the Cider Catalog, a word-frequency model was employed. The scraped apple varieties were treated as the tokens (units of analysis) in these analyses. In the Cider Catalog, Vermont had 6 single varietal ciders (representing 4.0% of all Vermont ciders), Virginia had 39 single varietal ciders (representing 12.6% of all Virginia ciders), and New York had 32 single varietal ciders (representing 4.9% of all New York ciders). *Figure 1* showcases the top 15 most commonly used apple varieties across cider products from Virginia, Vermont and New York, indicating broad differences in the uses of individual apple varieties across the three states. Some apple varieties were unique to certain states, such as the Albemarle Pippin and Porter’s Perfection apples described in Virginia and New York ciders respectively. Some apples were used much more often in certain states, such as the Rhode Island Greening appearing in 19 cider products in New York versus 3 cider products in Vermont and 0 cider products in Virginia.

When filtering all of the single varietal ciders, the researchers found that single varietal ciders can be flavored with non-apple adjuncts. The most commonly used apple varieties in non-flavored single varietal ciders were Northern Spy, Harrison, Albemarle Pippin, Gold Rush, Golden Russet, Arkansas Black, Winesap, Ashmead’s Kernel, Baldwin, and Black Twig. The most common apple varieties used in flavored single varietal ciders included Red Delicious, Granny Smith, and Pink Lady apple varieties in addition to the aforementioned varieties for non-flavored ciders. In cider products which were a blend of different apples, varieties were either “undesignated” (n = 125) or not mentioned at all (n = 122); but, when apple varieties were explicitly stated, the most commonly used varietals were Golden Russet, Northern Spy, Golden

Rush, Dabinett, Granny Smith, Jonagold, McIntosh, Rhode Island Greening, and Golden Delicious.

The most commonly used packaging formats described for cider products on the cider websites were 750 mL glass bottles (n = 230), 12 ounce cans (n = 161), 16 ounce cans (n = 85), and 500 mL bottles (n = 27). Many websites did not mention the packaging format of cider products (n = 486). The use of different apple varieties across canned and bottled packaging is shown in *Figure 2*. Bottled ciders tend to contain fewer table or culinary apple varieties and more cider-specific apple varieties, and bottled ciders explicitly stated apple varieties more often on cider websites.

## Website Description Analyses

In order to explore common terms used within website descriptions across different extrinsic factors, tf-idf analyzes were conducted for all cider products. *Figure 3* shows the results of high tf-idf terms across Virginia, Vermont, and New York, revealing broad differences in the individual terms used to describe cider products across the three states. All three states have various important terms related to place or the related state: for example, “ny”, “vermont”, “vt”, “burlington”, “virginia”, “shenandoah”, “northeast”, and “champlain” are indicated on the visualization. All three states have high tf-idf terms indicative of the sensory experience including “palate,” “aromas,” and “sight.” Virginia also has other potential, unique sensory terms such as “earthiness,” “brightness,” “mouthfeel”, and “caramel.” Virginia has “foods” has a high tf-idf term, suggesting that food pairings may be a particularly important feature of Virginia cider descriptions. Virginia and New York's set of high tf-idf terms is primarily inclusive of apple variety language; suggesting that what separates ciders from these states are primarily the apple varieties used in the cider. From New York, high tf-idf terms related to apple varieties include “russet,” “island,” “newtown,” “spy,” “rhode,” “greening,” and “baldwin.” From Virginia, high tf-idf terms related to apple varieties include “albemarle,” “harrison,” “twig,” and “winesap.” Interestingly, one of Vermont’s highest tf-idf terms is “manufactured,” though this term is not common in New York or Virginia cider descriptions. Unique to Vermont, various high tf-idf terms are related to the name of a cider product itself (i.e. "arlo" and "americran" are two cider product names) or the producer (i.e. "windfall", "citizen", and "eden" are all Vermont cider producers). Lastly, New York also has “ph,” “ta,” and “0.0” (referring to pH, titratable acidity, and 0.0g residual sugar, respectively) indicated as high tf-idf terms, suggesting that explicit mention of cider chemistry is a unique feature of website descriptions for products from this state.

An analysis of tf-idf terms across blended and single varietal ciders revealed that blended ciders contain many high tf-idf terms related to the cider-making process (i.e. “yeast,” “time,” “lees,” “vintage,” and “mix”) and cider sensory quality (i.e. “aromas,” “balance,” and “structure”). Blended ciders also include “summer” as a high tf-idf term, indicating that these products may be marketed for seasonal or occasion-based consumption. However, no obvious themes were able to be identified from the high tf-idf terms consistent with single varietal ciders and visualizations of these analyses were deemed not critically meaningful by the researchers.

*Figure 4* visualizes the most meaningful terms (i.e., high tf-idf terms) from the website descriptions across the two primary packaging formats (i.e., glass bottles and aluminum cans). As well, tf-idf analyses were calculated across 12 ounce cans, 16 ounce cans, 500mL bottles, and 750mL bottles. *Figure 4* indicates subtle yet important differences in the language used to

describe the products across packaging formats. Ciders in cans overall are distinguished by words without a clear overarching topic, though 12 ounce cans in particular had high tf-idf terms such as “fermented,” “pressed,” and “concentrate,” and the term “tart,” as a distinguishing sensory descriptor. Ciders in bottles overall were distinguished by terms related to apple varieties, chemistry, and cider production methods. For example, the terms “perfection,” “russet,” “newtown,” “esopus”, and “goldrush” are suggestive of apple varieties and the terms “disgorged” and “champenoise” are related production methods.

### Network Bi-gram Visualization

To explore words which commonly occurred together throughout the entire dataset, tokenization of website descriptors was performed using bigrams as described by Silge & Robinson (2017). *Figure 5* is a visualized network of the most frequently occuring bigrams across all website descriptions in the entire Cider Catalog. The bigram network visualization provided in *Figure 5* was not further segmented based on extrinsic product factors in order to maintain simplicity, given that bigrams are sparser than unigrams (Jurafsky & Martin, 2021), and to gain an overall glimpse of terms which are commonly used together. The biterm cluster related to residual sugar indicates a trend of website descriptions emphasizing sugar content, among other attributes, in website descriptions. Many biterms refer to apple varieties, such as “granny smith” and “kingston black,” and places, such as “blue ridge” and “finger lakes.” Some biterms are suggestive of production-related language, such as “bottle conditioned” and “6 months,” and “secondary fermentation,” and others are suggestive of sensory terminology, such as “soft tannins” and “fruit forward.” Interestingly, there is a bigram for “taste process,” suggesting that many producers use website descriptions to share information about the connections between the cider-making process and sensory attributes.

## Biterm Topic Modeling

A Biterm Topic Model (BTM) is an unsupervised learning method that finds “topics” in texts by identifying terms that occur in the same small context window more often than would be expected by chance. In order to explore topics across the text used in website descriptions, different “document corpora” were selected for fitting the BTMs: first, BTMs with various numbers of topics were fit to the entire cider catalog; second, separate BTMs were fit for each state for various numbers of topics. For each BTM, topics were manually labeled following agreement from the researchers. A topic was deemed coherent when the researchers agreed on topic identity based on the relevant biterms, and deemed incoherent when the researchers could not identify a consistent theme according to the biterms. For all models, only coherent topics are labeled.

*Figure 6* shows the seven-topic model of biterms across the whole corpus. The seven-topic model was selected because it showed stable topic coherence: all five topics from the five-topic model were found in the seven-topic model, while topics became inconsistent in the larger, nine-topic model. In this figure, the five coherent topics were labeled ***Food Pairing***, ***Apple Varieties***, ***Production***, ***Sensory***, and ***Flavorings*** as relevant themes emerging from website descriptions of cider products. The topic ***Sensory*** was the most stable topic in the corpus, originally appearing as a subjectively distinguishable cluster in the three-topic model. When the

topic model was expanded to the nine-topic model, the ***Flavorings*** cluster separated into three clusters each containing different flavoring-related biterms in addition to inconsistent terms. For example, a cluster containing the term ‘cranberry’ also contained the terms ‘sweet’ and ‘refresh,’ whereas another cluster containing the term ‘hop’ also contained the words ‘valley’ and ‘local’.

In *Figure 7*, the five-topic model for cider website descriptions from each of the three states showed the most coherent and non-repetitive topic clusters. Only coherent topics were labeled, including three ***Sensory*** clusters, three ***Production*** clusters, two ***Food-Pairing*** clusters, and one ***Apple Varieties*** cluster. Cider descriptions from New York were unique in their biterm clustering of words related to apple varieties, including the terms ‘northern’, ‘spy’, ‘golden’, and ‘russet’ (see *Figure 7(a)*), which refer to two apple varieties commonly used for cider-making: Northern Spy and Golden Russet (Proulx & Nichols, 1980). Vermont ciders had three clusters (red, yellow, and blue clusters) inconsistently including sensory biterms, although the yellow cluster included the majority of sensory-related terms (see *Figure 7(c)*). For example, *Figure 7(c)* shows the blue cluster including the terms ‘sweet’ and ‘fresh’ and the red cluster including the term ‘flavor’. This suggests that Vermont cider products may have some inconsistent sensory-related language in their website descriptions. We elaborate on the inconsistent occurrence of these and other terms in the following section.

## *Discussion and Conclusions*

The present study aimed to explore the language used by cider producers to explain and market their products via website descriptions, for cider products in three primary cider-producing states in the Northeast and Mid-Atlantic US. This study objective was accomplished using two text-mining approaches, “tidy-text” and biterm topic modeling workflows, which were selected for their accessibility and applicability to small-scale language projects. In general, text frequency, tf-idf, and biterm topic modeling were effective in producing effective insights across cider website descriptions. The BTM approach was particularly effective at helping to find coherent and consistent themes across website descriptions with some limitations.

The first portion of the text mining procedures involved simple frequency analyses of apple varieties used across the products from Virginia, Vermont, and New York, as well as across different packaging formats. Frequency analyses revealed that different apple varieties are used with different frequencies across the three states. *Figure 1* shows overall trends in how apples are used differently across the three states. The observation of certain apple varieties being used and described with a high frequency in each state aligns with other research about how certain apple varieties can be more prevalent in certain regions (Miles et al., 2020; Ostrom et al., 2022; Peck & Knickerbocker, 2018). Apple varieties were also a coherent cluster predicted using BTM across all website descriptions (see *Figure 7)*. However, apple varieties were only a coherent cluster for New York cider descriptions, not for Virginia and Vermont ciders (see *Figure 8*). Recent research has also described consumers' increasing interest in local and regionally-sourced apples and native apple varieties (Calvert et al., in preparation; Smith et al., 2021; Yenerall et al., 2022), and so it may be valuable for cider producers, particularly those in Virginia and Vermont, to emphasize their use of regionally-relevant apple varieties when applicable.

The present research also reveals broad findings related to the language used to describe cider products across Virginia, Vermont, and New York overall. Cider product descriptions from all three states include emphasis on sensory attributes, production information, and geography based on findings from both the text mining and BTM. Results of the single-word tf-idf approach suggest that Virginia cider products place more emphasis on food, New York cider products place more emphasis on chemistry, and Vermont cider products place more emphasis on proper nouns (i.e., locations, product names, and brand names). BTM revealed that food-pairing was in fact a consistent topic among both Virginia and New York products. Food-pairing information has been historically and culturally common for wine, both on websites and on product labels (Kelley et al., 2015; Mueller et al., 2010; Pettigrew & Charters, 2006; Spence, 2020b), but is less common within the product experience for beer (Martinez et al., 2017; Pettigrew & Charters, 2006). Though food-pairing is becoming more popular in the craft beer industry (Arellano-Covarrubias et al., 2022; Pettigrew & Charters, 2006; Spence, 2020b; Stoller, 2019), our results of food-pairing information being a dominant topic in cider descriptions may seem to suggest that cider producers are using food-pairing information as a way to analog cider closer to wine in terms of product expectations and the product experience. The same predictions may also apply to the use of apple varieties as a common topic among bottled (see *Figure 4*) and New York products; which may be an artifact of regional beverage and related packaging trends given that New York is home to 11 American Viticultural Areas and was ranked third as the most wine producing state in the US in 2020 (Conway, 2022).

It is worth discussing that *Figure 6* also reveals interesting trends related to cider production as evidenced by the biterms ‘secondary fermentation’, ‘bottle conditioned’, ‘native yeast’, ‘wild yeast’, and ‘wild fermentation’. These biterms suggest that the mention of wild fermentation methods are becoming common in product descriptions, presumably as a way to differentiate products. Wild fermentation methods are also trending in wine-making and brewing (Dillon et al., 2013; Molinet & Cubillos, 2020), though the details of these processes are not well-understood nor is the use of process-oriented terms regulated by industry stakeholders or governmental organizations. To re-emphasize, the ‘taste-process’ biterm in *Figure 6* suggests that cider producers use cider website descriptions to draw connections between production methods and intrinsic sensory attributes. These findings are consistent with consumer research on cider and other craft products demonstrating how consumers are interested in production-related information (Calvert et al., in preparation; Gómez-Corona et al., 2016, 2017; Lahne & Trubek, 2014; Paxson, 2013).

Sensory terms were a meaningful feature of the present research. Singular sensory terms were minimally showcased by tf-idf analyses across each state in *Figure 3*, but were the most stable biterm topic predicted with BTM across the whole data corpus, shown in *Figure 7*. This indicates that while few specific sensory terms are unique to cider products from specific places, cider website product descriptions are consistent in their use of sensory language. However, the sensory terms shown in *Figure 7* and *Figure 8* (from the BTM) include fairly simple descriptive terms (e.g., ‘fruit’) though sensory research on hard cider has demonstrated an abundance of more detailed sensory terms (e.g., ‘citrus’, ‘tropical fruit’, ‘strawberry’, ‘grape’;Calvert, Neill, Stewart, & Lahne, in review; Cole et al., 2022; Littleson et al., 2022). These findings suggest that the sensory language of cider marketing is not emphatically descriptive, which may align with discussion of cider descriptive language being unclear

(Demmon, 2019; Fabien-Ouellet & Conner, 2018; McGrath, 2019). In addition, the sensory terms ‘sweet’ and ‘dry’ both appear in clusters separate from the distinctly labeled ***Sensory*** topic in *Figure 6*. This may seem to suggest that ciders described as ‘dry’ are also commonly described according to how they are made, whereas ciders described as ‘sweet’ do not have any other clearly consistent descriptive attributes. Interestingly, traditional style cider is defined as less ‘sweet’ than modern style cider (Alexander & Ewing Valliere, 2020; Calvert et al., in review), and so the co-occurrence of ‘sweet’ and ‘traditional’ in the yellow cluster of *Figure 6* seem to reaffirm strong inconsistencies and a lack of clarity regarding the sweetness and dryness of cider products (Calvert et al., 2022; Kessinger et al., 2020; Phetxumphou et al., 2020). Sensory quality is a driving factor of consumer preference and willingness to pay for American cider products (Cole et al., 2022; Kessinger et al., 2020; Tozer et al., 2015), therefore it is crucial that sensory information be clear and meaningful so that consumers can know what tangible sensory attributes to expect from a cider product before purchasing and consuming.

Although the present study was able to effectively use text mining and biterm topic modeling to explore common terms and topics used to market and discuss cider products in an online space, this research has broad limitations. Most importantly, websites are not the primary means of marketing cider products and conveying product information between producers and consumers. In addition, this research only uses website descriptions from Virginia, Vermont, and New York as a snap-shot of cider product descriptions in the US. Though this research provides valuable insights as to how cider products are communicated via website platforms, more research into cider packaging information may also be relevant for making actionable recommendations for the industry.

Another critical limitation of the present research is that all analyses conducted using both the “tidy-text” approach and BTM require data processing decisions that are unique to the research team and heavily influential on the present findings (Jaeger & Rasmussen, 2021; Vidal et al., 2022). For example, the pre-processing steps taken in the present research included lemmatization, removal of common stop words, and selection of specific parts of speech (i.e., nouns, adjectives, and verbs) which were done to reduce data sparsity and allow for more coherent topic formation from the BTM. Relevant to the tidy-text approach, the present research followed procedures closely adapted from Silge & Robinson (2017) though wrangling techniques unique to the data-set and chosen by the researchers were also necessary (i.e., filtering out ‘NA’ when not relevant to the scope of the analysis in question). Other data manipulation and wrangling steps could have been conducted to deepen or change the information shown in the data visualizations, including running tf-idf across all packaging formats or consolidating similar packaging formats (i.e., cans versus bottles) or running more general frequency analyses. Lastly, a more holistic text analysis method (such as reflexive thematic analysis) could also supplement the quantitative methods of the current research to gain a better understanding of marketing approaches and cider product attributes or differences overall. Nonetheless, both the tidy-text mining and BTM approaches were valuable for understanding broad themes and patterns across cider products from Virginia, Vermont, and New York.

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## *Figures*

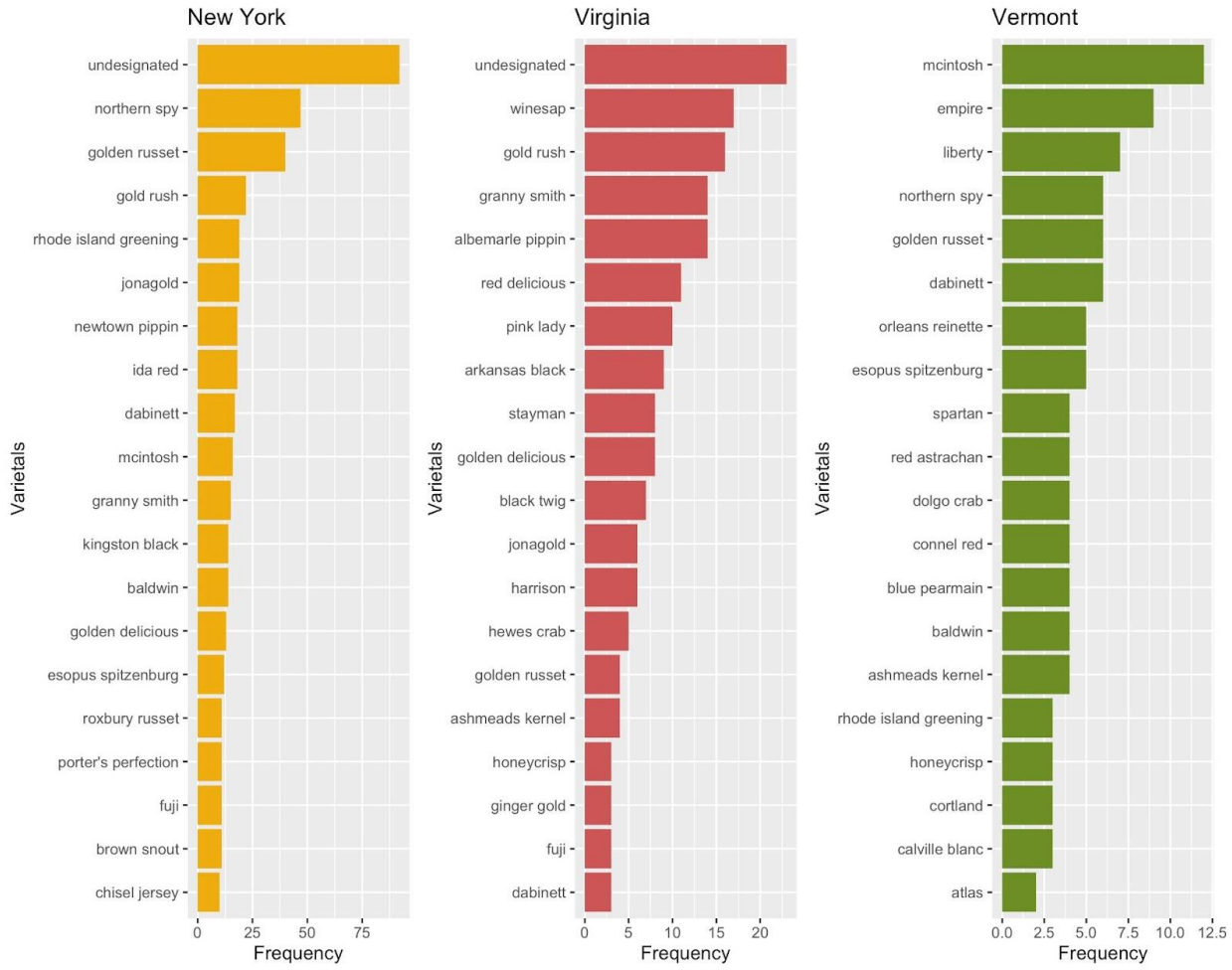


**Figure 6.1.** Specific apple varieties mentioned in website descriptions were counted across cider products from Virginia, Vermont, and New York. Apple varieties accounted for in the visualization must have been explicitly stated for cider products on the cider website. Null values (NA) were removed from the visualizations to improve readability of the varietal frequencies. The proportion of website descriptions that did not explicitly mention apple varieties were

35.66% (435/1220) in New York, 47.98% (202/421) in Virginia, and 35.23% (99/281) in Vermont.

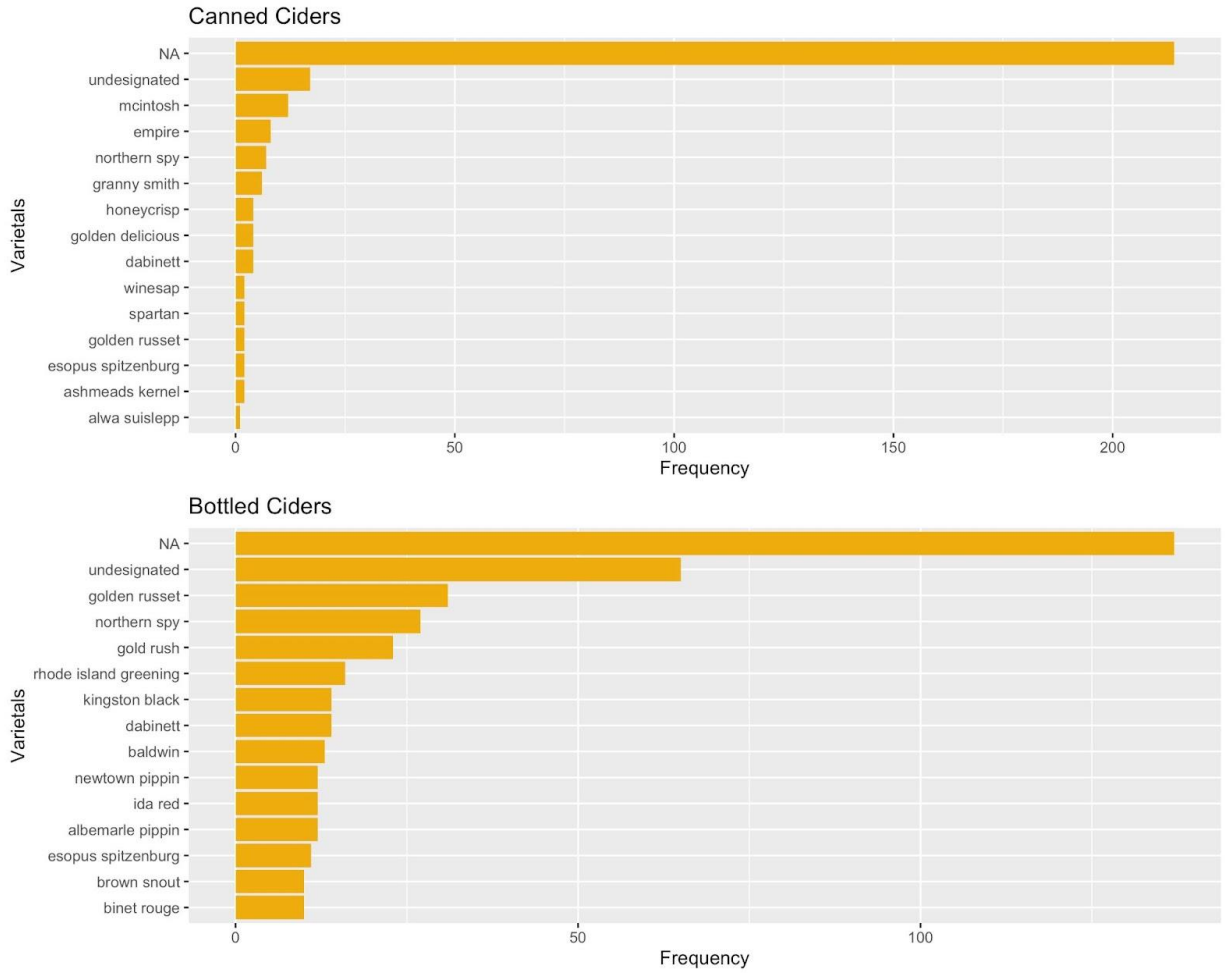


**Figure 6.2.** Specific apple varieties mentioned in website descriptions were counted across cider packaging formats. Apple varieties accounted for in the visualization must have been explicitly stated for cider products on the cider website, or the null value (NA) indicates that no apple varieties were indicated. Packaging formats accounted for in the visualization must have been explicitly stated for cider products on the cider website. These results indicate that canned ciders very frequently do not indicate the apple varieties (NA) used in a given cider product, whereas bottled ciders are more likely to include mention of apple varieties used in a cider product.

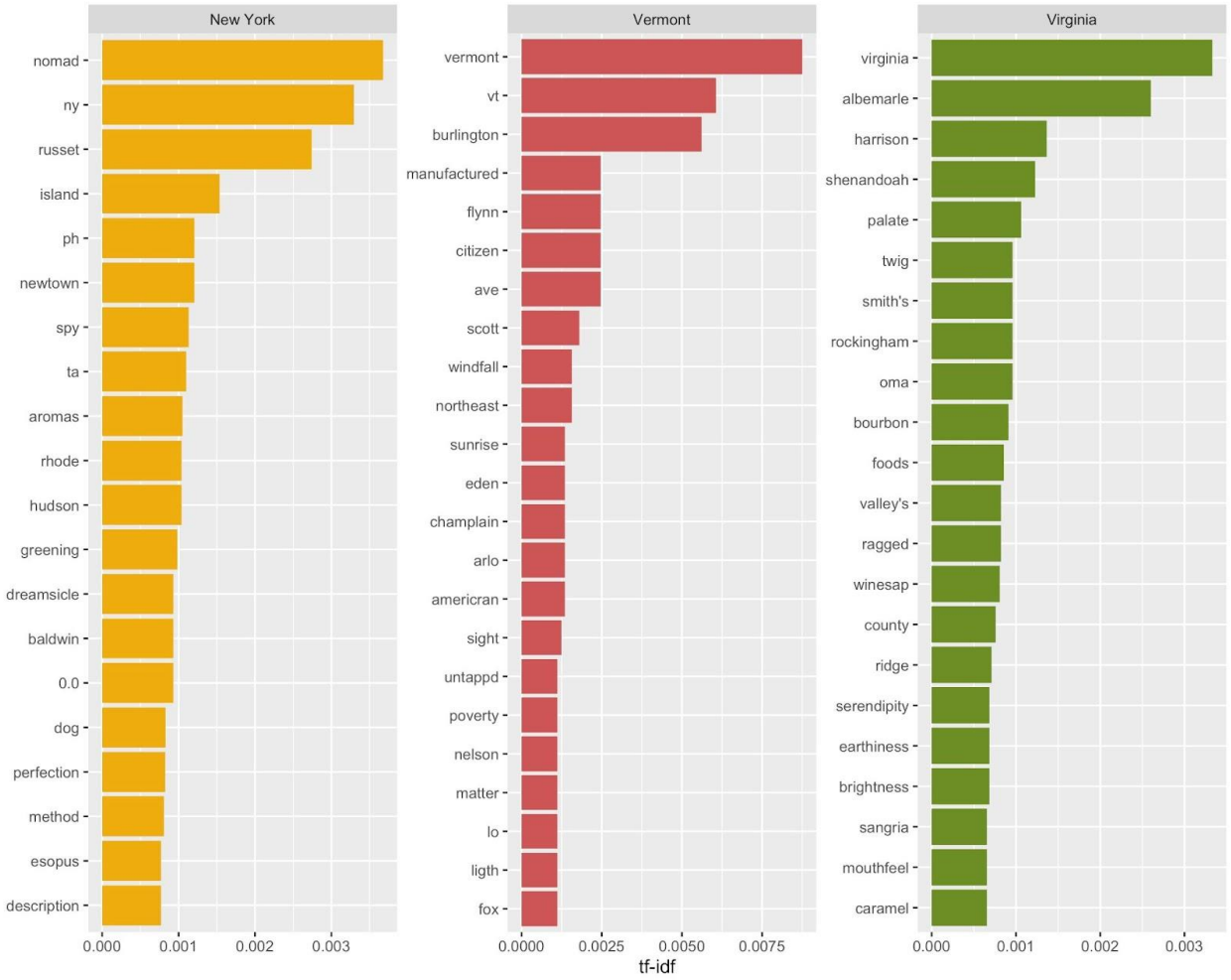


**Figure 6.3.** tf-idf of terms from website descriptions, compared across Virginia, Vermont, and New York shows that all three states have important terms related to proper nouns and geography. More sensory and food-related terms are unique to cider descriptions for products from Virginia, whereas the mention of chemical parameters (e.g., 'ph' and 'ta') are unique to New York cider product descriptions. New York and Virginia cider products have more unique terms related to apple varieties.

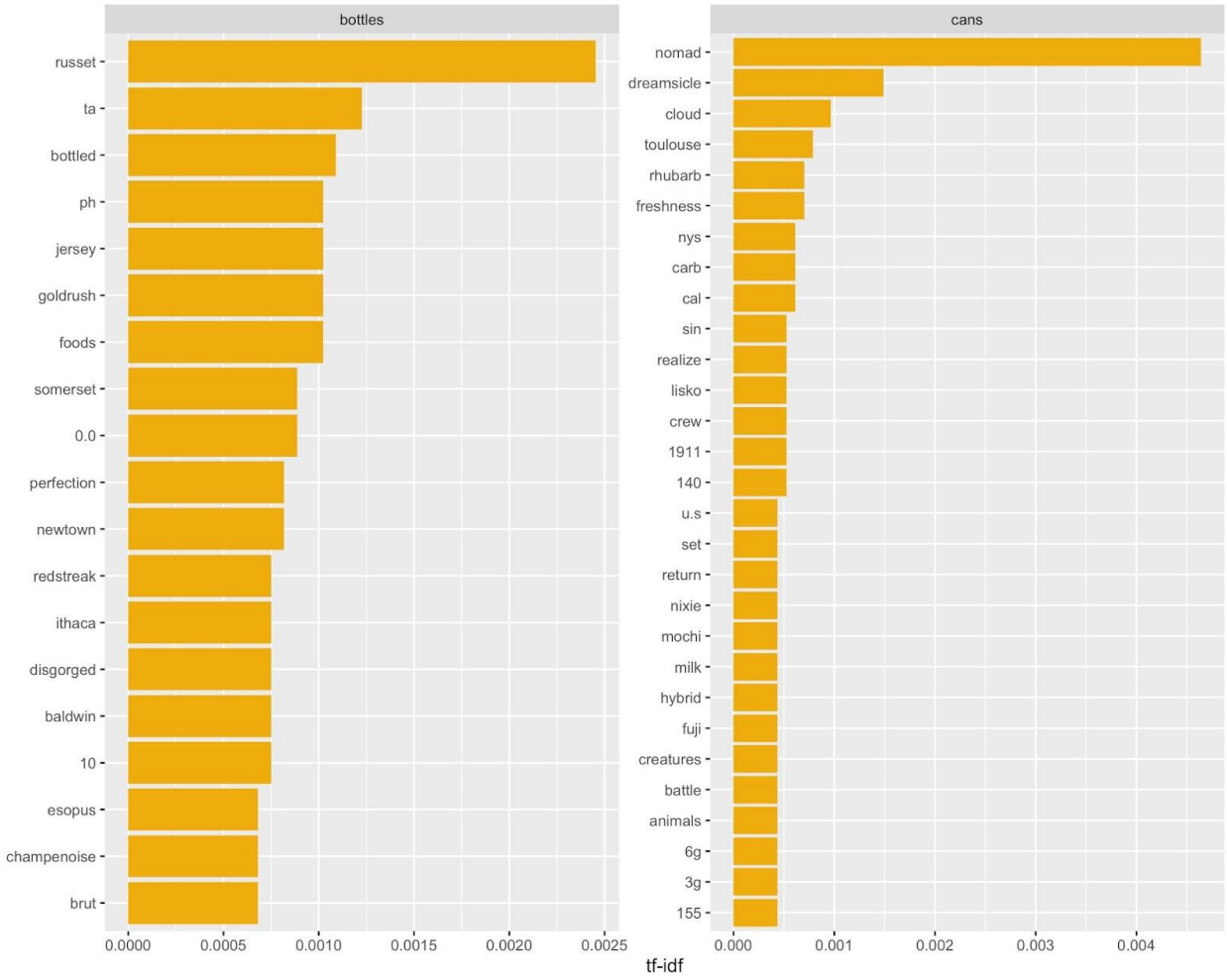


**Figure 6.4.** tf-idf of terms from website descriptions were compared across the two most common packaging formats, cans and bottles revealing that bottled ciders tend to emphasize terms clearly related to apple varieties, chemistry, and fermentation processes. Packaging formats accounted for in the visualization must have been explicitly indicated on the cider websites.

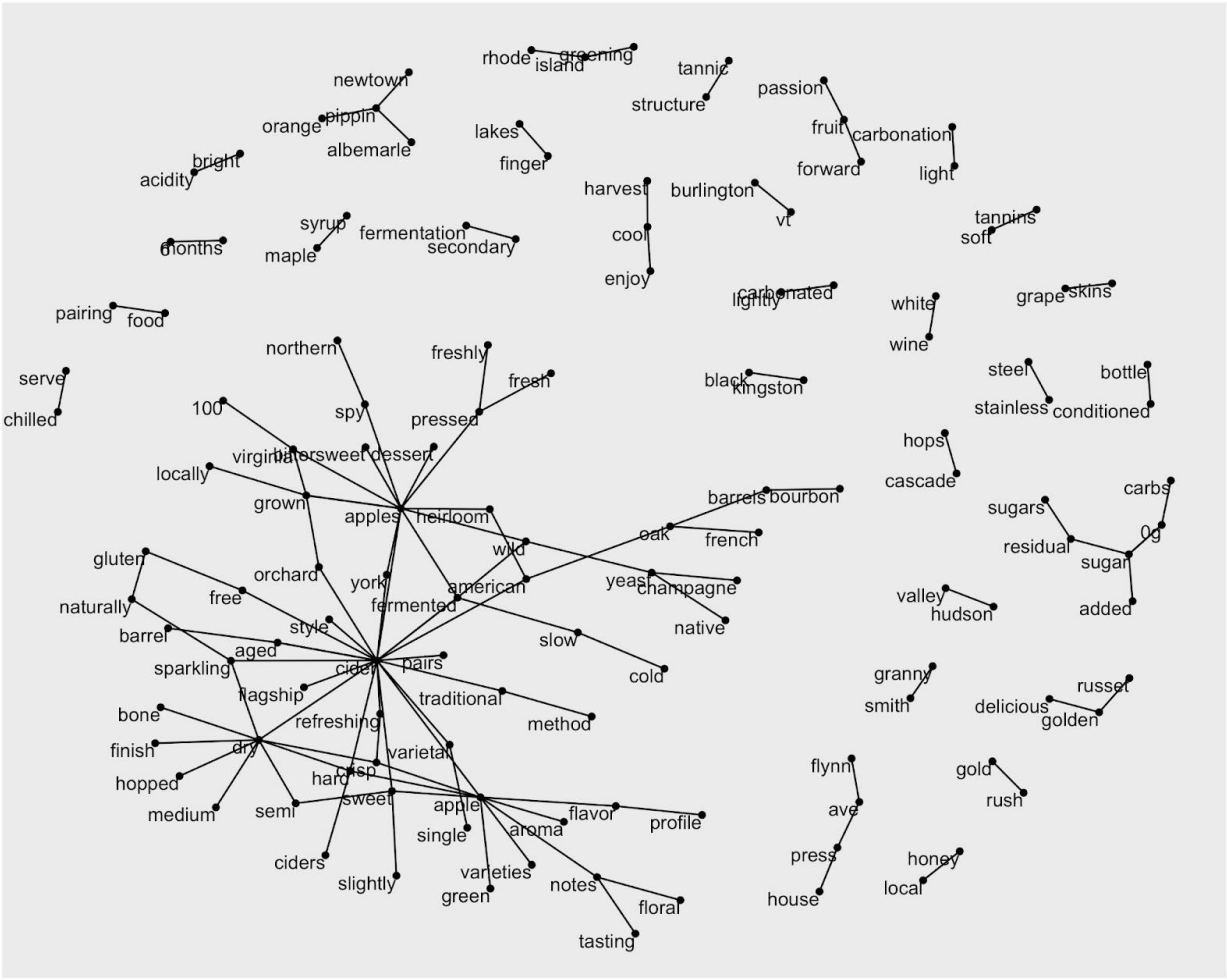


**Figure 6.5.** A visualized network of the most frequently occurring bigrams from the cider website descriptions, using connected nodes. This visualization shows common bigrams in cider website descriptions primarily related to apple varieties, sensory quality, production processes, and places. Interestingly, two bigrams could be inferred to refer to the consumption setting by discussing “food pairing” and “enjoy cool.” One network of clustered nodes emphasizes residual sugar content in cider. This visualization showcases some of the overarching topics across website descriptions.

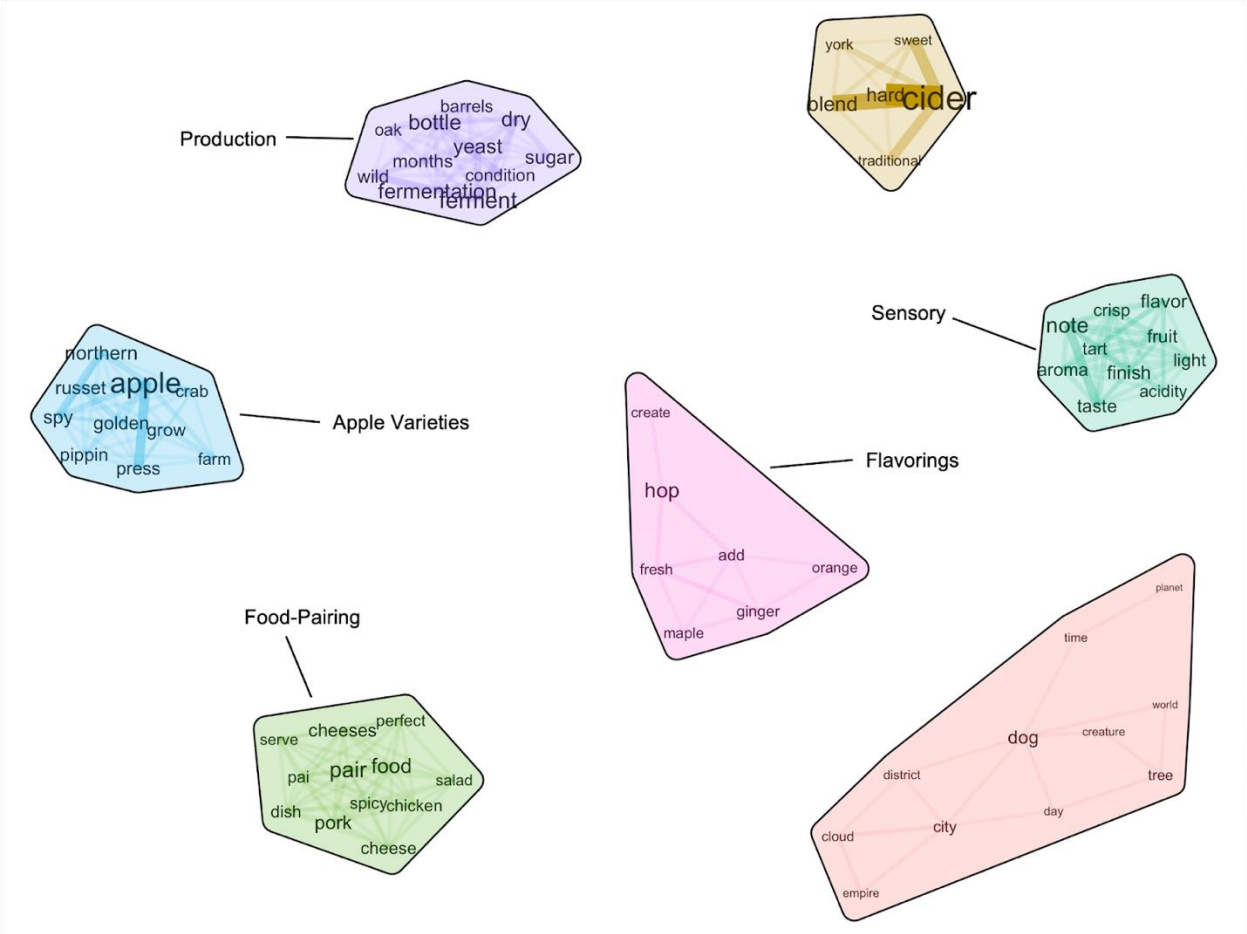


**Figure 6.6.** A seven-topic (k=7) biterm topic models of topics appearing per cider description across the whole corpus of data. Only coherent topics were labeled manually by the researchers. Inside of each topic cluster, the line width indicates how commonly two terms were associated with each other as a biterm. For example, ‘wild-fermentation’ and ‘blend-cider’ were terms commonly associated with each other. The orange, unlabeled cluster represents one incoherent topic cluster which is normal for BTM (Wijffels et al., 2021).

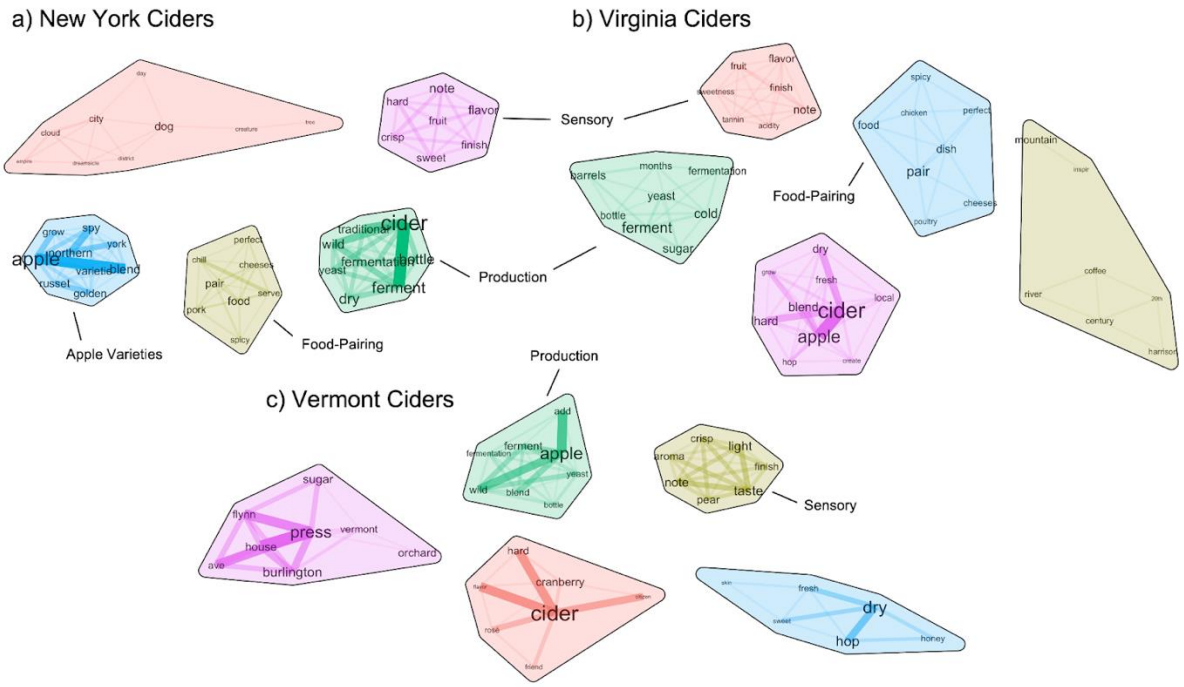


**Figure 6.7.** Three, five-topic biterm topic models of topics appearing per cider description per state, across the whole corpus of data. Topics related to ***Production*** and ***Sensory*** were consistent and coherent across all three states. New York (a) uniquely had a topic cluster related to ***Apple Varieties***, indicating that products from this state are often described including the mention of specific apple variety names. Vermont (c) did not have a coherent ***Food-Pairing*** cluster but did have a cluster including specific places (i.e., ‘vermont’ and ‘burlington’) and two clusters including flavoring-related terms (i.e., ‘cranberry’ and ‘dry-hop’).

# Chapter 7 - Conclusions and Recommendations

In this dissertation, I have employed both qualitative and quantitative research methods to explore the current American hard cider industry. I harnessed chemical and sensory methods to test the efficacy of the Merlyn Dryness Scale, originally developed by the New York Cider Association and industry stakeholders (New York Cider Association, 2019; New York Cider Association (NYCA), 2019). I utilized qualitative research methods as a framework for exploring consumer and producer preferences of cider and the cider-drinking experience. Using classical sensory Descriptive Analysis (DA), I determined a set of descriptive sensory attributes that can be used to characterize and discriminate a large representative sample of American cider products from the Northeast and Mid-Atlantic. Lastly, I applied novel text mining techniques to explore cider product descriptions on website platforms. Here, I review the observations and findings of my research, emphasizing those points which are particularly relevant for the US cider industry and broader alcoholic beverage industry, and I will discuss practical recommendations for future sensory science research. Finally, I will present major findings about cider sensory quality that may be of interest to key industry stakeholders.

## *Qualitative Research*

Qualitative research methods are the backbone of sociological and anthropological research because they enable researchers to holistically explore the experiences of specific people. Qualitative research is becoming increasingly popular in the food and sensory sciences specifically because they provide a means of exploring consumer preferences and perceptions related to food and beverage products (Gómez-Corona et al., 2016, 2017; Lahne & Trubek, 2014). Alongside social and cultural research, qualitative research in food science is becoming more detail-oriented – focusing on the nuances of regional food cultures and values, and how individuals' identities intersect with their food and beverage consumption behaviors.

The use of semi-structured open-ended questioning routes and contextual research environments makes qualitative research an invaluable tool for broadly questioning what consumers like about products. By being broad in scope, qualitative research allows researchers to explore all of the contextual factors that can contribute to the sensory experience, an increasing need within the sensory evaluation field (Meiselman, 2013; Meiselman et al., 2022). But, qualitative research is also valuable because it can gauge what motivates consumer interest and purchasing behavior, to get a preliminary glance at where trends are moving within specific industries. For example, some of the research presented in this dissertation could be interpreted as (1) consumers becoming increasingly considerate of agricultural processes involved in the making of food and beverage products, (2) the dominance of "flavored" beverages as temporary trend initiated by distribution pressures within the alcoholic beverage industry, and (3) how food producers are evolving to favor craftsmanship, artistry, and tradition as a type of livelihood that is in opposition to many of the ideals favored during the past century.

In considering consumers and producers' increasing interest in unique and agriculturally centered products, this represents a potential opportunity for qualitative research to be used to explore food, beverage, and agriculture trends in the current US food system. For example,

qualitative research could be used to explore consumer views of regional craft malt used in craft beer – being that local sourcing is heavily valued in the cider industry, *how* can the craft brewing industry evolve to cater to increasing desires to support local and regional agricultural systems? The number of craft maltsters is increasing nationwide, yet a thorough account of sensory quality and consumer preferences for beer made with craft malt is incomplete. I believe that qualitative research methods could also be useful for gauging consumer interest in new regional, agricultural commodities and even for exploring the potential of community sensory education to facilitate more thoughtful and satisfying consumption experiences.

In Chapters 4 and 5, I piloted the use of focus groups and interviews to explore not only cider consumers but also cider producers. Consumer preferences are often the basis of new product development and innovation in the food science field, though little research has investigated how producers view the consumption experience from their uniquely expert perspective. Producers are powerful in their ability to emplace their values and preferences onto the products that they make, and this has the potential to influence consumers' values and trends. With Chapter 5 specifically, I posit how research that holistically investigates producers' views of their products from a consumption standpoint may be a valuable tool for predicting industry trends and areas for innovation.

## *Language and Communication*

Text mining offers a quick and efficient way to explore communication related to food and beverages. Though many approaches to text mining in the food and beverage space have explored consumer-based texts, text mining of producer-based texts can be useful for understanding how products are marketed and differentiated. However, text mining approaches are extremely limited by data pre-processing decisions which must be clearly defined and communicated (Jaeger & Rasmussen, 2021; Vidal et al., 2022).

Chapter 6 of this dissertation showcases the use of both the "tidy-text" and BTM approaches for exploring patterns within cider product descriptions on websites. Many cider producers use language related to sensory quality, production processes, apple varieties, and food-pairing to describe their products – suggesting that cider producers closely align cider with wine. More research is needed to understand how cider products are communicated on packaging, and to consider the effect of legal requirements and restrictions in cider product marketing. It may also be relevant to consider how different consumers perceive language related to cider and wine marketing, and how this influences their consumption and purchasing behaviors.

## *Cider Sensory Quality*

From both the Merlyn Dryness Scale study and the classical Descriptive Analysis (DA) study, important themes emerged regarding the sensory quality of American hard cider. In Chapter 3, the DA study showed 29 descriptive attributes to be important for discriminating cider samples, revealing the wide diversity of sensory potential that is possible in cider products. The study also offered preliminary evidence to suggest that extrinsic factors, such as packaging and origin, have a connection to sensory quality differences among products. Interestingly, the DA

study revealed distinct clusters of ciders, broadly referred to as “funky,” “sour”, and “fruity” which closely align with previous sensory research on hard cider (Cole et al., 2022; Qin et al., 2018). Lastly, the DA study offers critical yet preliminary evidence to suggest significant sensory differences across modern and traditional ciders. Being that these style classifications for cider can be made with very different raw materials (Alexander & Ewing Valliere, 2020) and according to drastically different methods (see Chapter 5), these findings necessitate future research that explores how specific cider production methods can influence cider sensory quality.

In Chapter 2, I tested the Merlyn Dryness Scale’s efficacy in measuring and depicting a cider product’s sensory dryness and sweetness. This study involved measuring a cider’s dryness-sweetness using analytical chemistry and plotting a subsequent dryness-sweetness ‘score’ following a protocol originally developed by the New York Cider Association in 2018. Chemical processes were then followed with a sensory study where untrained consumers ranked the intensity of dryness-sweetness on a four-unit scale identical to the scale used in the chemistry-based Merlyn Dryness procedures. The results of this study revealed evidence of consumers’ wide variability in their dryness-sweetness perception and the inability of pure chemistry to predict sensory outcomes. These results align with other research showing how consumers use the terms ‘dry’ and ‘sweet’ inconsistently (Kessinger et al., 2020; Phetxumphou et al., 2020), which might suggest that these sensations are more complex than traditionally assumed; especially considering that bitterness, astringency, and acidity are sensory qualities that interact with dryness-sweetness perception in alcoholic beverages.

Results of the Merlyn Dryness Scale study suggest two-fold that (1) cider producers should not rely on chemistry and bimodal scales to communicate the sensory dryness and sweetness of their products, and (2) that more research is needed to better understand dryness and sweetness perception in alcoholic beverages. Particular attention should be paid to exploring how sweetness perception changes with chronic sugar intake (Jayasinghe et al., 2017; Trumbo et al., 2020; Wang et al., 2020), and how sensory dryness and sweetness influences affective responses to small tasting samples versus larger samples that are more consistent with traditional serving sizes. In continuing off of the former recommendation, cider producers may be more effective in communicating the sensory dryness-sweetness of their products by describing other tangible terms that correlate specifically more with either dryness (i.e., spice, bitter) or sweetness (i.e., fruity, candy), though more research and extension efforts may be crucial for providing cider producers with a more comprehensive word-bank of descriptive terms that best apply to American hard cider.

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