

Hard Cider Production & Orchard Management in the Pacific Northwest

A PACIFIC NORTHWEST EXTENSION PUBLICATION • PNW621



Hard Cider Production & Orchard Management in the Pacific Northwest

G.A. Moulton, C.A. Miles, and J. King
Washington State University Mount Vernon
Northwestern Washington Research and Extension Center

A. Zimmerman
Tulip Valley Vineyard & Orchard, Mount Vernon, WA

Acknowledgments

Much of what we have learned about cider making comes from Peter Mitchell, whose experience and input to this manual are appreciated. We highly recommend his series of classes (listed at <http://www.cider-academy.co.uk/>) for anyone with a serious interest in professional cider making.

All photographs by J. King unless otherwise noted.

Contents

INTRODUCTION.....	1
Defining Cider.....	1
History of Cider.....	1
Cider in America.....	1
Defining your Business and Style.....	2
Safety Measures.....	3
PART I: BASIC CIDER MAKING.....	3
Obtaining Fruit.....	3
Categories of cider apples.....	5
Characteristics of varietal ciders.....	5
Specialty cider apples.....	5
Rediscovered American cider varieties.....	12
Dessert apples.....	12
Crabapples.....	12
Cull apples.....	12
Processing Fruit.....	12
Mills.....	12
Presses.....	13
Containers.....	13
Juice Analysis.....	14
pH.....	14
Titratable acidity.....	16
Sulfites.....	16
Sugar and alcohol content.....	17
Fermentation.....	18
Yeast.....	19
Maturation.....	20
Preventing oxidation.....	20
Conducting malolactic fermentation.....	20
Monitoring sulfite content.....	20
Processing Base Cider.....	21
Blending.....	21
Barrel aging.....	21
Carbonating.....	21

Sweetening.....	22
Filtering	22
Bottling.....	22
Pasteurizing	22
Safety testing	24
Evaluating.....	24
PART II: BASIC CIDER ORCHARD MANAGEMENT	24
Sites and Soils.....	24
Soil quality	24
Orchard Layout	25
Rootstock Selection.....	25
Variety Selection.....	27
Pollinizers.....	27
Irrigation	27
Pruning.....	27
Thinning	32
Pest Management.....	33
Harvest Maturity Indicators	34
Harvest Methods.....	34
Storage	35
CONCLUSION.....	35
GLOSSARY	36
REFERENCES & FURTHER READING	39

INTRODUCTION

This bulletin provides guidance for making hard (fermented) cider (Part I) as well as growing apples intended for use in cider making (Part II). Commercial applications and methods are emphasized. Much of the information presented here on apple cultivar performance and fruit quality are results from studies at the Washington State University Mount Vernon Northwestern Washington Research and Extension Center (WSU Mount Vernon NWREC) that have applicability throughout the Pacific Northwest.

Although there is an extensive amount of information available on fermentation, styles of cider, selection of yeasts, and orchard establishment and management practices, no broad summaries exist. The approach here is to present overviews of these topics, with in-depth explanation where we feel it is most useful to understand cider production in its entirety. Resources providing details on all these topics are listed at the end of the publication, along with a glossary of related terms (identified in the text with bold font).

Defining Cider

Hard cider is fermented apple juice. In common American usage, raw apple juice that has not been filtered to remove pulp or sediment is referred to as fresh or sweet cider. The term “apple juice” indicates the liquid from pressed apples has been filtered to remove solids. In Europe, nonfermented apple juice (unfiltered and filtered) is referred to as juice, and fermented apple juice (unfiltered and filtered) is referred to as cider. In this publication, “cider” will be used to indicate fermented apple juice.

Worldwide, cider varies in alcohol content from less than 1.2% alcohol by volume (ABV) as found in French cidre doux, to 8.5% ABV in traditional English ciders. In the United States, the legal definition of cider for tax purposes specifies 7% or lower ABV; anything above 7% ABV falls into a different tax category—it can still be called cider, but is taxed at a different rate (Bureau of Alcohol, Tobacco and Firearms 1998). Cider tax is covered under RCW 66.24.210 in the state of Washington, ORS 473.035 in Oregon, and Section 23-105 of the Idaho Code.

History of Cider

It is unknown who discovered cider, or where in the world it was first made and consumed.

The first recorded references to cider date back to Roman times; in 55 BCE, Julius Caesar found the Celtic Britons fermenting cider from native crabapples (Watson 1999). The people of northern Spain were also making cider (sidra) around this time.

The Norman Conquest of England in 1066 resulted in the introduction of many apple varieties from France and sparked such interest in cider that it soon became the most popular drink after ale. Before long, cider was used as a means of exchange for tithes and rents, which continued later in America.

England and Ireland have the highest cider consumption as well as the largest cider-producing companies in the world. Cider is also traditional in western Europe, including Brittany and Normandy in France, and today is gaining new interest in both Europe and the United States (Holz-Clause 2003).

Cider in America

Only 9 years after first landing at Plymouth in 1620, European colonists planted apple trees in Massachusetts Bay, New England (Orton 1995). In Colonial America, cider was the most common beverage, and even children drank it in a diluted form. In many places, the water was not safe to drink and most homesteads had an apple orchard. Pressing (Figure 1) and fermenting fresh apple juice was the easiest way to preserve the large fruit harvest that came from even a modest orchard. Cider was also the basis for other products around the farm, such as vinegar.

Unlike in Europe, apple varieties in early America were usually not grafted and most fruit came from seedling trees. Johnny Appleseed (John Chapman) was very influential in spreading seedlings throughout the East and Midwest in the early 1800s. By the mid 1800s, farmers began to select for cider quality and grafted the varieties they liked best. This added new American varieties to the list of high quality cider apples.

By the late 1800s, cider was beginning to decline from its standing as the most popular beverage in the nation. By the early 1900s, most Americans had never tasted cider. Several social developments combined to essentially wipe cider from the collective memory of America. A major factor was the Industrial Revolution that brought more and more people from



Figure 1. Historic farm cider press, Jersey, United Kingdom. (Photo by Man vyi, Wikimedia Commons)

the farm to the city to live and work. Many orchards were abandoned, resulting in reduced production. Another factor was that unfiltered and unpasteurized cider did not travel well from farms to the new centers of population. Beer gradually replaced cider in the popular market due to the arrival of immigrants from Germany and Ireland and availability of inexpensive grain from the Midwest

The most dramatic decline in cider production coincided with the rise of the temperance movement in the late 1800s. Many farmers sympathetic to the cause took axes to their apple trees and swore off alcoholic beverages of any kind. Others started pasteurizing their pressed juice and marketing it as inoffensive apple juice. By the time Prohibition was enacted in 1919, the production of cider in the United States had slipped to only 13 million gallons, down from 55 million gallons in 1899 (Watson 1999). Over the next several decades, the once proud American tradition of cider making was kept alive by only a few local farmers and enthusiasts.

Now at the beginning of the 21st Century, cider consumption and production is popular once again. According to a market analysis, cider is one of the fastest-growing segments of the liquor industry (Rowles 2000) and might be following a similar path as microbrew beer where small producers are establishing a local following.

Many consider cider to be a drink of the future (Merwin et al. 2008).

Defining your Business and Style

In the United States, most consumers that try cider for the first time expect it to taste like apple juice, only with a bit of a kick. A traditional cider product that is strongly flavored may not appeal to first-time consumers. With time, however, cider drinkers tend to develop a more sophisticated palate that allows them to appreciate the more complex flavors of traditional ciders. Developing a product line that includes several flavors and styles, from highly aromatic, low acid, and low tannin to less fruity cider with stronger acidity and more tannin, will have the widest appeal to both new and traditional cider drinkers (Figure 2).

To start and maintain a successful cider business, you must first identify your targeted customers. The next step is to determine what apple varieties are available to you. Will the available apples produce the style of cider you are trying to attain, or will you need to grow or purchase specialty apples? The final stage to establishing a successful cider business involves calculating your costs of production and setting a price for your product that enables you to earn a profit. Making a business plan that includes estimates for different scales of production will help you



Figure 2. Different styles of cider targeted to specific consumer groups.

see how the business can evolve to meet growing demand and changing consumer preferences.

A marketing plan is critical to determine how you will present and offer your product to best reach your targeted customers and convince them to buy from you. It may be necessary to conduct product and marketing tests to determine if your product has acceptable taste qualities and if your customers will pay the price you need to make the business successful. A marketing analysis done at Cornell (Rowles 2000) discusses specific aspects of marketing strategies as applied to cider. As for many agricultural enterprises, marketing is often the most challenging part of the business, while cider production is usually the most enjoyable. Because the two aspects are largely distinct and yet both vitally important, it may be worthwhile to find a marketing specialist.

Safety Measures

In addition to the initial financial preparations, anyone considering starting a cider business should be familiar with pertinent local, state, and federal guidelines and regulations regarding food safety and site sanitation. One of the most important of these includes Hazard Analysis and Critical Control Points (HACCP). We highly recommend that if you undertake commercial production of hard cider, you develop and implement a HACCP plan to prevent physical and chemical health risks. If you make and sell fresh, unfermented cider, the Food and Drug Administration (FDA) requires a Juice HACCP

plan due to associated microbial contaminants. See FDA (2009) for further details regarding HACCP. Other safety considerations are noted throughout the manual as they pertain to the topics covered.

PART I: BASIC CIDER MAKING

The cider-making process discussed below was developed through practical experience, work with cider makers, and information provided in classes presented by Peter Mitchell at the WSU Mount Vernon NWREC.

Cider making can be divided into the following steps, which are presented along with the primary objectives of each in Figure 3:

- Obtaining fruit—by growing or purchasing
- Processing fruit—grinding, milling, juice extraction, settling, and racking
- Juice analysis and adjustments—determining Brix (sugar content), specific gravity, pH, and titratable acidity; making additions as needed to balance these aspects of the juice to ensure quality and storability
- Fermentation—adding yeast, yeast nutrients, racking, clarifying, stabilizing
- Maturation—aging the bulk cider to allow it to clear and develop into a good usable base¹
- Processing your base cider(s)—blending, sweetening, carbonating, filtering or fining as necessary, bottling, pasteurizing

Obtaining Fruit

If you operate a commercial dessert apple orchard and are looking for an income source that uses cull fruit, cider is an option. If you do not currently operate an orchard, cull fruit can be purchased from local orchards or regional warehouses. Cull fruit are rejected from the fresh market primarily because they are blemished, incorrectly sized, or misshapen. Using cull fruit for cider can be an inexpensive way to take advantage of apple varieties currently available in your area. However, fruit internal quality

¹ During maturation, oxidation must be prevented and sulfites managed to prevent microbial spoilage. The goal is to avoid faults and produce a high quality, clear, base cider.

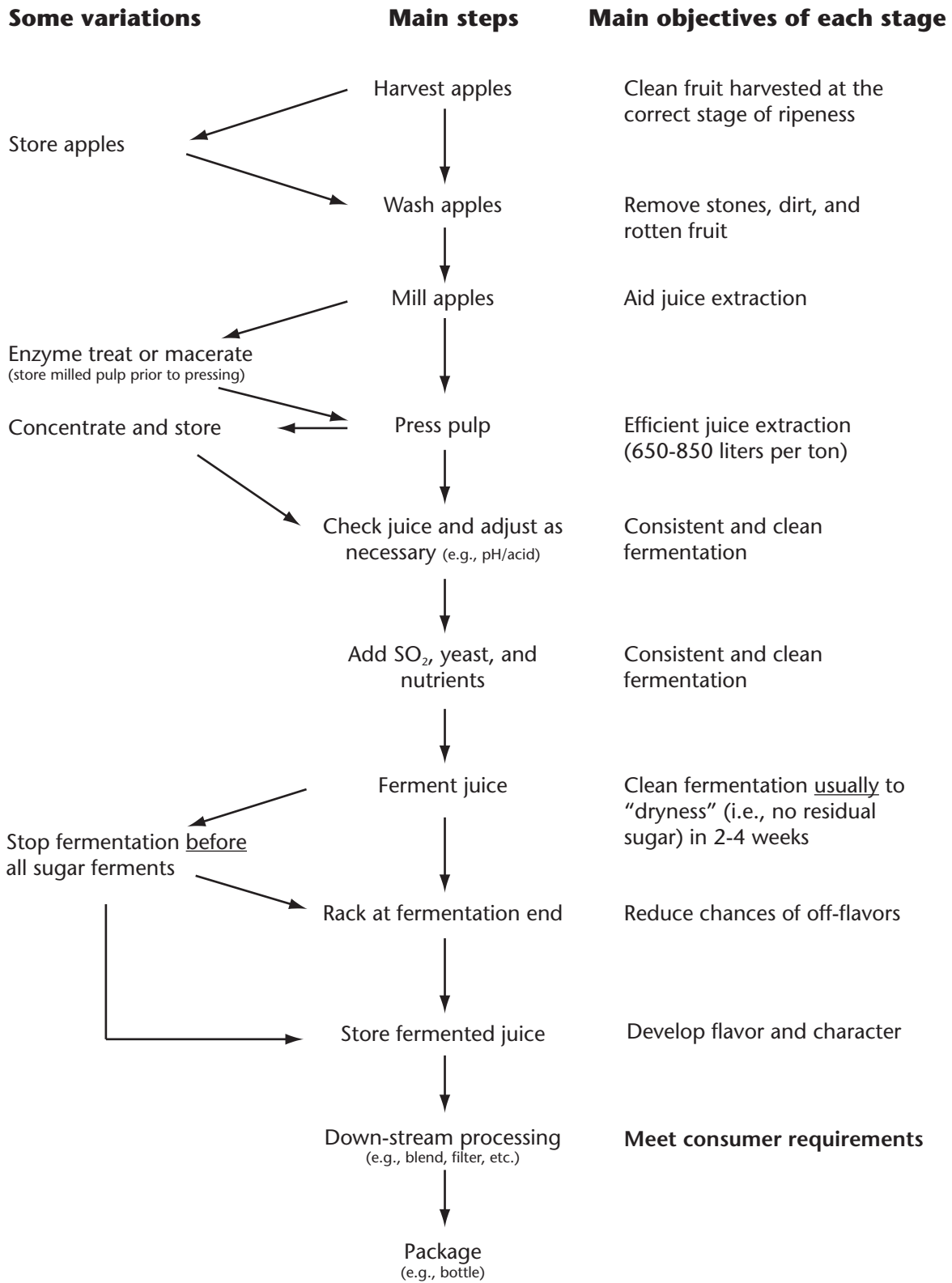


Figure 3. Flow diagram of the cider-making process (adapted from Mitchell 2009).

is extremely critical for high quality cider production. Check fruit harvest indices to make sure the cull fruit are fully ripe and have the flavor qualities you desire for your cider. Discard fruit with rot and physical damage, which can cause **patulin** contamination.

Most established orchards in the United States produce dessert apples which may be suitable for developing an inexpensive cider targeted to the mass market. High volume and low price are key to the success and profitability of this product. While dessert apples alone do not normally make a distinctive high-end cider, with creative processing you can achieve a good product, or blend with cider apples.

Specialty cider apples are essential to produce a gourmet, artisan style of cider. Cider apples are generally higher in tannins and/or acidity than dessert apples and are used to produce traditional high-quality cider. Specialty orchards that grow cider varieties are relatively uncommon, so you may want to consider planting your own cider apple orchard or working with an orchardist to add cider apples to their operation.

Raw or reconstituted juice are also options for cider making, and may be all you need to start your cider operation. However, juice concentrates have different quality ratings and some are not suitable for fermentation. Before buying juice for cider making, determine whether any microbial growth inhibitors were used to preserve it. If possible, do a small fermentation test batch to make sure that the juice will ferment with no problems, and is acceptable in flavor and quality.

If you currently make cider with purchased fruit or juice and are considering planting an orchard of your own, be sure to carefully weigh the many factors that affect orchard production before you take action. Cider professionals generally consider it easier for a fruit grower to learn to make cider than it is for a cider maker to learn to grow fruit.

Categories of cider apples

Cider apples are classified into 4 categories (Cider Advisory Committee 1956):

1. **Bittersweet**—high in tannin, low in acid
2. **Bittersharp**—high in tannin, high in acid
3. **Sharp**—low in tannin, high in acid
4. **Sweet**—low in tannin, low in acid

Table 1 categorizes many of the classic apple varieties used to make cider in Europe. Bittersweet and bittersharp varieties are grown specifically for high quality full-bodied ciders. Our observations in cider orchards at the WSU Mount Vernon NWREC indicate there is a positive correlation between an apple's flesh density and its juice viscosity. Viscosity is desirable because it gives body, or a creamy thick mouthfeel, to cider. A less viscous cider appears thin and can seem watery. Thin ciders that are less complex in aroma tend to make the best sparkling ciders. Both bittersweets and bittersharps produce ciders that are viscous and often astringent, giving a fuzzy feel on the tongue. Bittersweets, as the term implies, contain the two opposing tastes in the skin and flesh. Bittersharps are more sour due to a higher acid content (Morgan and Richards 1993). In Europe, bittersweets and bittersharps are considered desirable apples for almost all types of cider. This assessment is spreading to the United States, where cider-apple growers are planting increasing acres of these varieties. Many dessert apples fall into the sweet and sharp categories.

Characteristics of varietal ciders

A cider made with the juice from a single variety is referred to as a varietal cider. The characteristics of some varietal ciders that were evaluated at the WSU Mount Vernon NWREC are presented in Tables 2 and 3. Many of these varieties show promise in the region due to good orchard productivity and cider characteristics. Good cider characteristics include pleasant aromas, flavors, acidity, bitterness, astringency, and body that combine to create complexity and quality in a cider. A balanced cider is achieved by blending the right proportions of all these elements.

Specialty cider apples

Specialty cider apples are often bittersweet and bittersharp types that produce viscous and complex ciders. If these varieties are not readily available in your area, you may have to grow them yourself or contract with an orchardist to grow them for you, particularly if your goal is to produce a handcrafted well-textured cider with a range of aromas.

Bittersweets typically have more tannins than dessert apples, a characteristic which can be picked up by the tongue. Bitterness is imparted

Table 1. Classification of commonly grown apples used in cider (Williams 1975).

SWEETS	BITTERSWEETS	SHARPS	BITTERS HARPS
<i>Neutral</i>	<i>Tannic, astringent</i>	<i>Acidic, tart</i>	<i>Tannic, acidic</i>
T ¹ <0.2, A ² <0.45	T>0.2, A<0.45	T<0.2, A>0.45	T>0.2, A>0.45
Cider Apples	Cider Apples	Cider Apples	Cider Apples
Berkeley Pippin	Ashton Brown	Breakwell	Cap of Liberty
Court Royal	Jersey	Brown's Apple	Dufflin
Eggleston Styre	Ball's Bittersweet	Coleman's Seedling	Foxwhelp
Geeveston Fanny	Bedan	Dymock Red	Improved Foxwhelp
Peau de Vache	Broadleaf Norman	Fair Maid of Devon	Kingston Black
Pomme Gris	Cimitiere	Frederick	Stoke Red
Sweet Alford	Chisel Jersey	Hereford Redstreak	Worcester
Sweet Coppin	Cow Jersey	Ponsford	Pearmain
Vagnon Flocher	Dabinett	Tom Putt	
Wayne	Gilpin	Winter Stubbard	Crabapples
Woodbine	Harry Masters'	Yellow Styre	Dolgo
	Jersey	York Imperial	Hagloe
Standard Apples	Knotted Kernel		Joeby
Baldwin	Medaille D'Or	Standard Apples	Martha ³
Ben Davis	Michelin	Bramley's Seedling	Red Siberian
Golden Russet (UK) ³	Nehou	Cox's Orange Pippin ³	Transcendant ³
Fameuse ³	Porter's Perfection	Crimson King	
Golden Russet (USA) ³	Reine des Hatives	Esopus Spitzenberg	
Grimes Golden	Reine des Pommes	Gravenstein ³	
Hubbardston	Royal Wilding	Jonathan	
McIntosh ³	Sherrington Norman	Northern Spy	
Rambo	Somerset Redstreak	Rhode Island Greening	
Rome Beauty	Stembridge Jersey	Ribston Pippin ³	
Roxbury Russet ³	Taylor's	Stayman	
Sops of Wine	Tremlett's Bitter	Wealthy ³	
Stark	Vilberie	Winesap	
Westfield Seek-No-Further	Yarlington Mill		
Winter Banana ³			
	Standard Apples		
	Lindel		
	Newtown Pippin		
	Red Astrakhan		

¹T = percent tannin

²A = percent titratable malic acid

³Aromatic apples contributing bouquet or nose to cider

by “hard” tannins, whereas astringency is the product of so-called “soft” tannins. Hard tannins tend to be short molecules and soft tannins are larger molecules. Tannin molecules have an affinity for each other, and as a cider ages over time, smaller hard tannin molecules combine to form larger soft tannin molecules (Merwin et al. 2008). Bitterness is expressed as taste, whereas astringency is expressed as mouthfeel (Mitchell 2006). Tannin concentration varies from year to year with each crop, which is an important consideration when blending. There is a range of bitterness within the bittersweet category, and as you approach 0.2% tannins in cider, bitterness is intensified to a recognizable degree. Often

very bitter apples are also astringent. Normally, bittersweet varieties have a pH above 4.0 and therefore need to be blended with an acid variety to create a suitable cider (this is further discussed below in Adjusting pH).

For those who like high tannin apples, **Vilberie** and **Dabinett** are considered very desirable varieties. **Vilberie** has a stout flavor that some may consider too harsh. **Dabinett** is slightly milder but still has a medium to high range of tannins; it is one of the most commonly used cider varieties in the United Kingdom. In our trials at the WSU Mount Vernon NWREC, **Vilberie** had a tendency to be alternate bearing,

Table 2. Percent tannin, Brix, pH, and titratable malic acid in juice of apples grown and tested at the WSU Mount Vernon NWREC in 2008 and 2009, listed in descending order by percent tannin in 2009.

Sample	Tannin %		Brix		pH		Malic Acid g/l	
	2009	2008	2009	2008	2009	2008	2009	2008
Medaille D'Or	1.75	– ¹	17.2	–	4.37	–	3.54	–
Vilberie	0.91	0.41	12.0	14.2	3.60	3.89	3.43	3.86
Amere de Berthcourt	0.68	DNF ²	14.0	DNF	4.47	DNF	2.26	DNF
Reine des Pommes	0.67	DNF	14.9	DNF	4.21	DNF	3.38	DNF
Nehou	0.61	0.22	14.2	15.0	4.56	4.01	3.10	3.81
Frequin Rouge	0.57	0.19	12.2	10.8	4.57	4.20	2.58	2.73
Red Jersey	DNF	0.26	DNF	11.0	DNF	4.38	DNF	1.72
Domaines	0.52	0.24	15.0	16.0	4.53	4.16	2.09	2.79
Lambrooke Pippin	0.51	–	14.4	–	2.86	–	10.61	–
Stembridge Jersey	0.48	–	12.9	–	4.69	–	2.41	–
Coat Jersey	0.48	–	11.8	–	3.72	–	1.93	–
Doux Normandie	0.48	–	13.0	–	3.58	–	3.86	–
Kermerrien	0.46	0.34	12.8	14.0	3.86	4.00	2.47	2.23
Royal Jersey	0.45	DNF	12.2	DNF	4.13	DNF	1.50	DNF
Stoke Red	0.43	0.30	13.2	13.0	4.04	3.50	6.22	7.50
Chisel Jersey (NY)	0.43	–	14.2	–	4.93	–	1.88	–
Yarlington Mill	0.38	0.11	14.0	11.0	4.97	4.04	1.72	2.68
Foxwhelp	0.33	–	14.0	–	3.01	–	10.18	–
Cimitiere	0.33	–	11.2	–	4.90	–	1.39	–
Breakwell Seedling	0.32	0.12	11.0	10.4	3.17	3.43	5.36	6.97
Muscat de Berney	0.32	–	12.0	–	3.68	–	2.57	–
Ribston Pippin	DNF	0.11	DNF	14.8	DNF	3.48	DNF	6.54
Dabinett	0.32	0.23	14.0	14.2	4.90	4.47	1.34	1.93
Blanc Mollet	0.30	–	11.4	–	4.27	–	1.50	–
Harry Masters' Jersey	0.30	DNF	12.0	DNF	4.18	DNF	1.72	DNF
Metais	0.30	–	12.0	–	4.36	–	1.29	–
Major	0.29	0.22	13.4	14.8	4.24	4.42	1.82	1.82
Frequin Tardif	0.28	–	12.0	–	4.36	–	2.58	–
Tremlett's Bitter	0.28	0.17	11.8	12.2	2.88	3.44	9.86	10.34
Campfield	0.27	–	13.0	–	4.63	–	2.63	–
Cap O'Liberty	0.26	0.18	11.0	12.0	2.89	3.38	9.87	13.67
Kingston Black	0.26	0.13	13.4	13.0	3.22	3.70	5.63	5.90
Brown Snout	0.26	0.08	12.0	13.0	3.73	4.10	3.00	2.95
Bulmer's Norman	0.25	0.17	11.2	11.8	3.94	4.06	1.88	1.77
Muscadet de Dieppe	0.24	DNF	14.0	DNF	3.84	DNF	2.30	DNF
Marin Oufroy	0.24	–	14.2	–	4.47	–	2.84	–
Frequin Audievre	0.23	–	12.0	–	4.75	–	1.40	–
Dymock Red	0.21	0.19	13.0	14.4	4.07	4.29	1.82	2.03
Peau de Vache	0.19	0.09	11.0	12.4	3.71	4.08	3.00	2.52
Taylor's	0.19	–	12.2	–	4.15	–	1.66	–

Table 2 (continued). Percent tannin, Brix, pH, and titratable malic acid in juice of apples grown and tested at the WSU Mount Vernon NWREC in 2008 and 2009, listed in descending order by percent tannin in 2009.

Sample	Tannin %		Brix		pH		Malic Acid g/l	
	2009	2008	2009	2008	2009	2008	2009	2008
American Forestier	0.19	–	11.8	–	3.63	–	1.98	–
Harrison	0.19	–	16.0	–	2.94	–	10.08	–
Taliaferro	0.19	–	10.2	–	2.87	–	6.81	–
Golden Russet	0.18	0.10	15.0	18.0	3.93	3.72	7.93	6.38
Court Pendu Rose	0.17	0.07	12.4	13.0	2.87	3.41	8.79	10.02
Track Zero Seedling	0.17	–	12.0	–	3.97	–	1.61	–
Bouteville	0.16	–	12.0	–	4.43	–	1.17	–
Bramley's Seedling	0.16	0.11	10.0	12.8	3.63	3.35	10.18	10.29
Zabergau Reinette	0.16	0.10	11.9	16.4	3.85	3.66	6.27	8.95
Tom Putt	0.16	0.08	11.0	11.2	3.77	3.52	6.27	7.24
Whidbey	0.15	0.07	11.9	14.4	3.96	3.53	4.88	8.30
Grindstone	0.15	–	11.4	–	3.18	–	5.25	–
Sweet Alford	0.15	0.06	11.0	14.6	4.77	4.32	1.34	2.89
Finkenwerder Herbstprinz	0.15	0.06	14.6	14.0	2.96	3.44	11.36	10.13
Redstreak	0.15	0.06	12.0	12.0	2.99	3.36	8.74	9.86
Smith's Cider	0.12	–	11.0	–	3.15	–	4.28	–
Mott Pink ³	0.11	–	12.0	–	3.16	–	7.08	–
Roxbury Russet	0.11	0.07	16.4	17.0	3.31	3.85	4.77	5.41
Crow Egg	0.10	0.10	10.2	14.0	4.01	3.66	3.27	5.63
Reine des Hatives	DNF	0.10	DNF	14.0	DNF	4.34	DNF	2.47
Granniwinkle	0.10	0.05	10.4	12.0	1.58	3.80	1.82	3.48
Maude	0.10	–	12.0	–	3.40	–	4.82	–
Court Pendu Plat	0.10	–	13.0	–	2.93	–	7.72	–
Freyberg ³	–	0.01	–	14.0	–	3.96	–	3.48

¹Blank (–) indicates data not collected
²DNF = Did not fruit, mature tree in alternate year
³Dessert apple

while **Dabinett** was more consistent in bearing from year to year and had a more manageable tree habit of wide angle branches and no **blind wood**. See Part II of this publication for discussion of alternate bearing and blind wood (pp. 27–30, 32).

On the other end of the spectrum, **Brown Snout** has lower tannin than many of the bittersweets, yet produces a viscous, smooth cider that is less austere than some of the more bitter varieties. This variety makes an excellent base cider and can be used as the primary ingredient for high quality blended ciders.

Several bittersweets show promise throughout the Pacific Northwest. **Kermerrien**, **Frequin Rouge**,

Amere de Berthcourt, and **Reine des Pommes** are French varieties that can significantly boost bitterness in a blended cider. Preliminary data from WSU suggest they are good choices in terms of yield, productivity, and cider quality. In addition, these varieties bloom earlier than several other bittersweets and may be worthy of trial in areas prone to fire blight. **Yarlington Mill** produces a mildly bitter cider with good body and aroma. Although alternate bearing, it has a desirable tree habit with good branch angles and little blind wood. **Chisel Jersey** is a highly rated bittersweet that is not acidic. In Scott's Catalogue of 1893, this variety was described as "perhaps the most esteemed bittersweet sort in the Somerset orchards" (Copas 2001).

Table 3. Characteristics of varietal ciders evaluated at the WSU Mount Vernon NWREC.

Variety	Description	Color	Aroma	Ac ¹	Bit ²	Sw ³	Astr ⁴	Bdy ⁵	Flavor Profile
Amere de Berthcourt	Moderately to highly bitter; bittersweet	Gold	Confectionary, estery, honey, aspirin, fresh cut grass, vanilla	L	M-H	L	M-H	M	Astringent with long bitter aftertaste, good blender to boost bitterness. Honey, vanilla, artificial fruit.
Braeburn	Sharp, dessert and culinary apple	Straw	Apple skins, confectionary, pear	L-M	L	L	L	L	Cider thin, not complex, would benefit from blending. Slightly acidic, lacks aftertaste, bland.
Brown Snout	Mildly bitter; bittersweet	Amber	Apple, nutty, banana, maple, caramel, resinous	M	M	L	M	H	Good stand alone single-varietal cider; good body, balance, and mouth feel; juice will need acid adjustment prior to fermentation. Dark viscous cider. Easy to drink even as a single varietal. Apple, slight banana, nutty, butterscotch.
Brown's Apple	Sharp	Amber	Citrus, banana, butter, fresh cut grass, rummy	M	M	L	M	M	Good balance, a little bland, would benefit from blending, nice nose. Citrus, apple, butterscotch, honey.
Bulmer's Norman	Mildly bitter; bittersweet	Gold	Apple, honey, confectionary, pear drops	M	L-M	M	L-M	M	Good balance, light body for a bittersweet, a little thin. Aftertaste short-lived but astringent, builds and lingers, refreshing.
Cap of Liberty	Moderately bitter, bittersharp	Gold to slightly amber	Apple, bittersweet, spicy, butterscotch, citrus, cidery	M-H	M-H	L	M	M-H	Unbalanced, bitterness lingers, body viscous but not heavy. Long bitter aftertaste, sour; complex spicy flavors will be enhanced when acids are balanced.
Dabinett	Moderate bittersweet	Amber	Apple, banana	M	M-H	L	H	M-H	Has body and astringency, tannins are harsh and tend to dominate flavor. Good alone for those who like a stout cider, otherwise blend to soften tannin; good nose. Apple, raisins.
Foxwhelp	Mildly bitter; bittersharp	Amber	Slightly spicy, banana, nutty	H	L-M	L	L-M	M	No outstanding character, will add some body and a lot of acid to blends; earthy tones. Best use as blender. Sharp apple, pear, butterscotch.
Frequin Rouge	Moderately bitter, bittersweet	Amber golden	Cidery, nutmeg, medicinal, clove, vanilla, honey	L-M	M-H	L	M-H	M	Viscous with some body, astringent with complex aromas. Can be a single varietal but may be best as a blender to boost tannins. Cidery, nutmeg, vanilla, slightly warms the back of the mouth, moderate bitter aftertaste lingers.

Table 3 (continued). Characteristics of varietal ciders evaluated at the WSU Mount Vernon NWREC.

Variety	Description	Color	Aroma	Ac ¹	Bit ²	Sw ³	Astr ⁴	Bdy ⁵	Flavor Profile
Gala	Sweet; dessert apple	Straw	Appley, pear drops, fruit salad, lemon	L-M	L	L-M	L	L	Cider thin but not watery, some fruit aroma, benefits from blending for more body. Bland, short aftertaste, not complex but interesting blend of aromas.
Gravenstein	Sharp; culinary and dessert apple	Gold	Applesauce, apple, pear drops	M	L	L	L	L-M	Good aroma but cider not complex, sour with a lingering tang, fruit should be fully ripe. Short aftertaste, refreshing character, easy to drink, sweetening would enhance balance.
Harry Masters' Jersey	Mildly bitter, bittersweet	Amber	Woody, apple, wine like, resinous, floral, pineapple, perfume	M	M	L	M	M	Good body and balance, good stand-alone varietal, fruity aroma. Melon, berries, butterscotch, pine needles, tart, nutty.
Jonagold	Sharp; dessert and culinary apple	Straw	Apple	M	L	L	L	L	Adds fruit both in aroma and flavor—best if used to bring fruitiness to a cider apple with tannins and body. Citrus, apple.
Kermerrien	Moderately bitter; bittersweet	Straw to gold	Cidery, spicy, bubblegum, estery, nutmeg, banana, medicinal, woody, honey	L-M	M-H	L	M-H	M	Cidery, creamy, bitter aftertaste lingers but is not harsh, good blender. Fruity, banana, bubblegum, creamy.
Kingston Black	Mildly bitter; bittersharp	Gold to amber	Apple, spicy, nutty	M	M	L	M	M	Good single-varietal cider, tannins are soft, good balance, wonderful apple flavor jumps all over the mouth. Citrus, apple, butterscotch.
McIntosh	Sharp; dessert and culinary apple	Straw	Wine like, apple, tropical, berry, floral	M-H	L	L	L	L	Brings aroma to a cider—great for blending to enhance the bouquet, but not good as a single varietal, lacks body & tannin. Wine like, apple, fruity, toast.
Melrose	Sharp; dessert and culinary apple	Straw	Butterscotch, fresh cut grass, pear, cidery, cooked banana	M	L	L	L	L	Thin, uncomplicated cider, unpretentious, balance fair, slightly acidic. Short aftertaste with slight citrus flavor.
Michelin	Moderately bitter; bittersweet	Amber golden	Apple, banana, nutty, berry, gooseberry, floral esters, caramelized apple	M	M	L	M	M	Can stand alone but benefits from blending. Good strong apple/berry aroma, tastes like cooked apple, bland. Fruity, apple, berry.
Muscadet de Dieppe	Mildly bitter; bittersweet	Dark amber	Apple, banana, nutty, tropical, fresh cut grass	M	M	L-M	M	H	A lot of body, good balance. Very good single-varietal cider; even when fermented to dryness still keeps a slightly sweet taste. Fruity, apple, spice, nutty, honey, syrup.

Table 3 (continued). Characteristics of varietal ciders evaluated at the WSU Mount Vernon NWREC.

Variety	Description	Color	Aroma	Ac ¹	Bit ²	Sw ³	Astr ⁴	Bdy ⁵	Flavor Profile
Pinova (Corail, Sonata, Pinata)	Sharp; dessert apple	Gold	Apple skins, confectionary, sweets, pineapple	M	L	L	L	L	Cider thin, balanced, not complex, lacks body. Short aftertaste with citrus flavor.
Reine des Pommes	Moderately to highly bitter; bittersweet	Amber golden	Apple skins, rosin, spice, citrus, lychee fruit, honey, tropical candied fruit, artificial fruit flavor	L-M	M-H	L	M-H	M	Good balance, fruity with high tannins, good single varietal stout type. Builds complexity, boosts tannins when blended. Full body, creamy, good fruit character, bitterness lingers and builds (astringency). Apple skins, spice, citrus.
Tom Putt	Sharp	Straw	Apple skins, bruised apple, lemon, fresh cut grass	L	L	M	L	L-M	Mildly sharp cider, creamy mouth feel, balanced. Slightly sweet, lightly creamy, thin aftertaste that tapers off quickly.
Vilberie	Highly bitter; bittersweet	Amber	Apple, spicy, floral, estery	M	H	L	H	M	Very bitter with high astringency. Bitterness harsh, dominant; best used in blending. Is very stout cider. Metallic taste, tea bags (tannic), aftertaste of copper penny, woody bark.
WSU AxP Crab	Mildly bitter; bittersharp; culinary crabapple	Straw	Apple, spicy, nutty, tropical, floral, fresh cut grass	H	M-H	L	H	M	Great for blending, provides a lot of mouth feel because of its astringency. Some also like it as a single-varietal cider. Fruity, wine like, citrus, vanilla.

¹Ac = acidity

²Bit = bitterness

³Sw = sweetness

⁴Astr = astringency

⁵Bdy = body

Bittersharps normally have high tannin content, similar to bittersweets, but are also moderately to highly acidic. Most bittersharps fall into the right pH window (3.3–3.8) for producing a highly suitable varietal cider (see Juice analysis, p. 14, for more on pH). **Kingston Black** is a bittersharp that makes a well balanced varietal cider with a strong apple aroma. It has some tendency to alternate bearing, but seldom fails to produce a crop. **Cap of Liberty** has some bitterness but is not overpowering. It can be on the sharp side, so can benefit from acid reduction or blending with a bittersweet variety. However, its naturally high acidity makes it a good stand-alone varietal cider especially suited to organic cider production. Trees tend to be alternate bearing.

Porter's Perfection is a very late bittersharp variety that often produces small fused fruit. Trees tend to be vigorous, productive, and healthy, with acidic juice. It can produce an excellent varietal cider, though blending is needed to achieve a balanced product. **Stoke Red** is another bittersharp option reported to produce a good varietal cider. Trees have shown good disease resistance in several areas, earning it the nickname "Neverblight" (Morgan and Richards 1993). One drawback with this variety is its tree habit, which tends to be twiggy and slow to come into production.

Other specialty cider varieties are sharps and sweets. **Tom Putt**, **Breakwell**, and **Dymock Red** are sharps, while **Pomme Gris**, **Sweet Alford**, and **Sweet Coppin** are sweets.

Rediscovered American cider varieties

Colonial Americans preserved a few favorite cider varieties by grafting, and though this practice was not common, some of these varieties have been rediscovered. Using American heirloom varieties may help stimulate historical interest in lost U.S. cider culture. Older dessert apple varieties like **Northern Spy**, **Baldwin**, **Golden Russet**, and **Roxbury Russet** have long been used in American cider making (Merwin et al. 2008). **Harrison**, **Granniwinkle**, and **Campfield** are among the rediscovered heirloom varieties. In an initial evaluation of a regional cider, **Harrison** made a rich, high quality product. If you are targeting your cider to the connoisseur, adding American heirloom varieties has the potential to set your business apart from others.

Dessert apples

Most common, standard dessert apples are sharps and sweets. In cider evaluations at the WSU Mount Vernon NWREC, both **McIntosh** and **Jonagold** are classified as sharp, though McIntosh is more aromatic than Jonagold. McIntosh has a relatively light, thin flesh which disappears quickly in the mouth, and makes a good base for a sparkling cider. In addition, the notable McIntosh aroma can enhance the bouquet of a more stout cider. Gravenstein has a denser flesh texture than McIntosh and produces a more viscous cider. While Gravenstein juice is not as viscous as some bittersweet varieties, its texture characteristics make it useful as a good base cider. Several dessert russet fruits such as **Ashmead's Kernel**, **Golden Russet**, **Roxbury Russet**, and **Karmijn de Sonnaville** are sharps but also have unique aroma characteristics that contribute some wonderful flavors to a cider blend. If you have dessert apples, evaluate their varietal cider characteristics to determine how they may contribute to your cider operation.

Crabapples

If you have **crabapples** in your orchard that you planted as pollinizers, it is worth testing the fruit in a varietal cider (see the Pollinizers section in Part II for details on growing, p. 27). Crabapple fruit typically is high in tannins, falling into either the bittersweet or bittersharp category, and can be pressed and blended to enhance a cider. **Manchurian crab** is a common pollinizer

crabapple that adds tannins and acidity to cider blends. **WSU AxP** is a bittersharp crabapple seedling cross from the WSU Mount Vernon NWREC that showed scab resistance in field trials.

Cull apples

While cull fruit from existing orchards can be used successfully to make cider, it is necessary to carefully and consistently assess the quality of the fruit. Most cull fruit are blemished, incorrectly sized, or misshapen; however, the critical factors for cider production are good internal fruit quality, full ripeness, no rot, and minimal physical damage.

Processing Fruit

Select processing equipment that is most economical and efficient for your scale of production and that will allow you to change your production practices as your business evolves. Cleanability and sanitation are also critical considerations when selecting equipment.

Mills

Historically, apple milling was done in a circular stone trough with a rotating stone wheel drawn by a horse. Scratcher or grater mills, in which a wheel with coarse knives or graters rotates against a fixed surface, became popular in the late 1800s and form the basis of the high-speed mills used in most modern cideries today (Figures 4 and 5). These modern mills can be sized to match the scale of most operations (Lea 2008).

Cull out rotten and damaged fruit before washing and milling. In many operations, sorters remove such fruit as it is unloaded from the orchard bin onto a belt. Use a pressure spray of clean water on the apples as they go down the roller before entering the grinder to remove soil and debris. This significantly reduces potential contamination problems. Good sanitation prevents microbial contamination and reduces binding of SO₂ in the juice (see Sulfites, p. 16). Pathogens and toxins produced by microorganisms (e.g., *Escherichia coli* and patulin) are destroyed by the creation of alcohol during the fermentation process. However, these contaminants are a concern if you add fresh juice after fermentation (see Sweetening, p. 22).



Figure 4. Milling fruit before pressing.

Presses

Once the fruit has been milled, it is referred to as **pulp**. A press extracts juice from fruit pulp. Rice hulls and enzymes are sometimes added to the apple pulp before pressing to increase the efficiency of juice extraction. After pressing is completed, the squeezed pulp, called pomace, can be added to compost or mixed into animal feed. There are essentially two types of presses: batch and continuous.

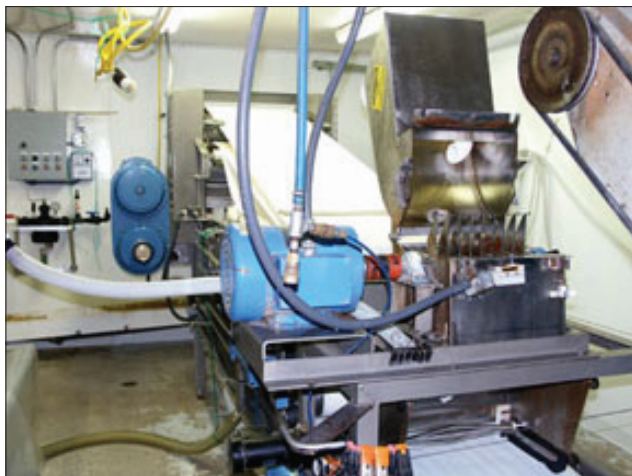


Figure 5. Commercial-scale hammer mill. (Photo courtesy of Kickapoo Orchard)

Batch press. In medieval times, wooden screw presses were used to press the juice from apple pulp. The apple pulp was first built into a cheese using alternating thin layers of pulp and straw. The straw provided drainage channels so that when pressure was applied with the screws, the juice flowed to a receiving tray and into a barrel. This same principle is used in many modern large and small cider presses (Figures 6 and 7). Wooden or plastic slats have replaced the straw, and a hydraulic pump provides the pressure, but the principles remain the same. Small-scale hand screw versions of the batch press (Figure 8) are readily available from specialist suppliers. Horizontal piston presses, as well as bladder presses specially designed for apple juice extraction, are used in large cider factories. A piston press includes a steel cylinder with flexible nylon drainage channels; the cylinder is filled with pulp and gradually compressed (Lea 2008).

Continuous press. This is a relatively new type of press that became popular in the mid 1900s. Pulp is continuously fed into the press and is squeezed between two woven steel and nylon belts (Figure 9). This type of press is more often used in large commercial juice and cider factories. Less labor is needed to run this type of press, but juice extraction efficiency is also reduced. Most continuous presses are expensive, which often limits their use to larger operations.

Containers

Carefully select your fermentation and storage equipment. Only certain types of materials are



Figure 6. Artisan-scale hydraulic press in operation.



Figure 7. Accordion-type hydraulic press.



Figure 9. Commercial-scale continuous press. (Photo courtesy of Kickapoo Orchard)



Figure 8. Small-batch home cider combined mill and press.

suitable for processing fruit juice and cider. Avoid most metals, with the notable exception of food-grade stainless steel, which is excellent but costly. Iron and copper should never be in contact with juice or cider because these metals will dissolve and transfer undesirable colors and flavors to your product.

For fermentation and storage tanks, certified food grade stainless steel, plastics, fiberglass, and epoxy resins are preferred. Fermenting or storage of cider in used whiskey or rum barrels can add complexity to your product. However, be aware that wood contains pores which may harbor harmful microorganisms. If you intend to use wooden barrels, make sure that they are well cleaned with high pressure hot water and possibly steamed, scoured, and well rinsed. Glass is also satisfactory, but relatively expensive.

Juice Analysis

Analyze juice for pH, titratable acidity (TA), and sugar content before beginning the fermentation process. Each parameter has specific target values that are required for safe, stable, and high quality cider making. The following are some basic guidelines for how to measure these parameters and adjust the juice to meet the target values. Testing requires a small sample (250 ml) of juice at or shortly after pressing.

Set up a clean room separate from the processing area as a laboratory to store, use, and clean glassware for performing the juice analyses. Follow a laboratory safety program such as outlined by the Occupational Safety and Health Administration (OSHA). Obtain flasks, beakers, pipettes, burettes, and chemicals as described in the techniques below. Be sure to label all chemicals clearly and note expiration dates, as chemical products are no longer reliable beyond their labeled expiration date. *In a laboratory setting, always wear protection for your eyes and skin. Do not store or consume food in this area.*

pH

The pH of your apple juice is important because it impacts the antimicrobial activity of SO₂ in the resulting cider (Figure 10). Before beginning fermentation, your juice pH should fall within

the range of 3.3 to 3.7. The lower the juice pH, the stronger the acidity and the less risk of microbial problems (i.e., spoilage). Juice with low microbial activity potential is therefore more stable. When making organic cider, which usually contains no added sulfites, it is critical to adjust the juice pH as close to 3.3 as possible to minimize potential microbial problems. Juice with a pH higher than 3.7 is likely to become contaminated by microbes.

Measuring pH. The pH of apple juice is the measure of its hydrogen ion concentration. A pH reading is the negative log of the free hydrogen ions in the juice. Each whole number represents 10 times the number of hydrogen ions as the preceding whole number. For example, a juice with a pH of 3.0 has 10 times more free hydrogen ions than a juice with a pH of 4.0.

You cannot judge the pH of a juice by simply tasting it. A juice with a pH below 3.3 (such as many dessert apple varieties have) may taste good because its high acidity is being masked by the sugar present in the juice. However, fermentation will convert the sugar to alcohol and result in a dry cider that may be too acidic to drink. On the other hand, juice with a pH greater than 3.7 may also be appealing in taste, but because it is more prone to microbial spoilage, it will require a larger addition of sulfites to prevent microbial contamination, or may even make SO₂ applications totally ineffective.

The most common and accurate way to measure pH is with a pH meter. A litmus paper pH test, though relatively inexpensive, is subjective (each person may interpret the color slightly

differently) and the reading is to the closest whole number, so its degree of precision is somewhat low. We therefore recommend a pH meter with a shatter-resistant probe for commercial cider production to ensure safe and high quality products.

Adjusting pH. There are two ways to adjust the pH of apple juice. For both, do a small sample first to test adjustments. The more natural method is to blend the juices from different varieties, where each juice has a different pH. Sharp varieties tend to have a pH of 3.3 or below, while bittersweet and sweet varieties tend to have a pH above 4.0. Most bittersharps fall within the range for good cider production and do not usually need adjustments. Many dessert apple varieties are sharp and so are good choices to blend with classic bittersweet cider varieties. Conduct small laboratory blending tests to determine the proportions of the different varieties to produce the desired blend. Adjust the juice blend until the pH is in the 3.3 to 3.7 range. Record the proportions of each juice and then mix the large batch using the same proportions.

The other method of adjusting juice pH is to add food grade chemicals. Calcium carbonate (CaCO₃) will increase juice pH, whereas malic acid will reduce juice pH. Approximately 1.2 g/l of calcium carbonate lowers titratable acidity (TA, described next) by 0.1%, while 1 gram malic acid per liter raises TA by approximately 0.1%. After lowering or raising the TA with calcium carbonate or malic acid, respectively, wait for 2 hours and then check the pH to see if it is in the desired range. Calcium carbonate may take up to 24 hours to complete its action. When the

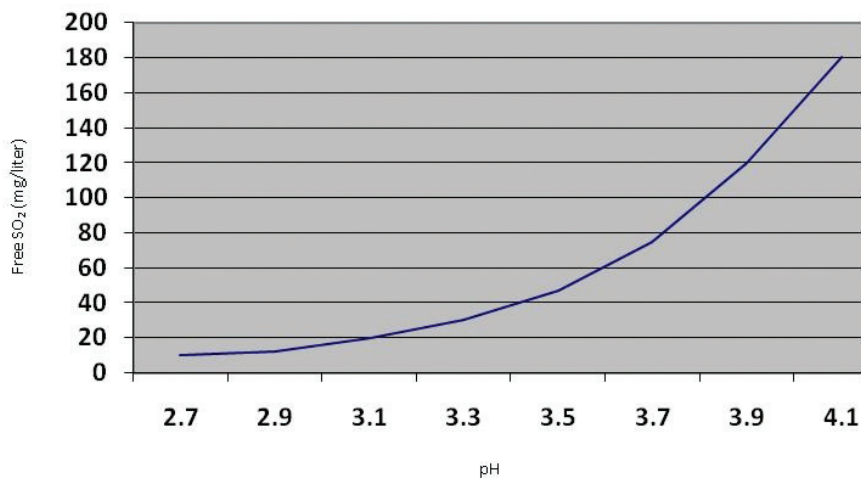


Figure 10. Amount of free sulfur dioxide (SO₂) needed at corresponding pH to prevent microbial spoilage in apple juice and cider (adapted from Mitchell 2009).

pH of the sample batch is in the desired range, calculate the ratios and apply to the main batch. An alternative method of reducing the acidity in cider is with malolactic bacteria (see Conducting malolactic fermentation, p. 20).

Titrateable acidity

Titrateable acidity (TA) has a strong impact on a cider's flavor (how sour a cider is). TA is the measurement of organic acids or the potential total free protons (ionic strength) in apple juice. Malic acid is the primary titrateable organic acid found in apple juice. Each organic acid has a different potential to add free protons to a juice solution. Because each juice has a different proportion and form of organic acid, this enables two juices with the same TA value to have a different pH, or vice versa.

Measuring titrateable acidity. Titration (Figure 11) is a common laboratory method of chemical analysis used to determine the concentration of organic acid strength (free protons) in apple juice. Always conduct titrations and keep test samples in a specifically designated laboratory away from the production area. It is also important to wear safety goggles, a lab coat, and acid-resistant liquid-proof gloves during the process.

The first step in the procedure is to fill a titrate burette that has a metering valve with a 0.2N NaOH (sodium hydroxide) solution. Record the starting level of the 0.2N NaOH solution



Figure 11. Titration method for determining pH and titrateable acid in apple juice.

in the burette, measured at the bottom of the **meniscus** of the NaOH solution.

The second step in the titration procedure is to prepare a dilute juice sample. There are several ways to do this, but we recommend pouring a 25 ml juice sample into a 250 ml flask, adding 125 ml of deionized or distilled water, swirling the flask by hand or on a stirrer plate (place magnetic stirring rod in the flask) until the juice and water are thoroughly blended, and adding 4 drops of phenolphthalein to the diluted juice in the flask.

Finally, place the flask with the diluted juice sample under the metering valve of the burette. Slowly dispense the 0.2N NaOH solution into the juice sample, swirling the flask continuously until a pink color appears. As the solution turns to pink but fades quickly, add drops of NaOH until the pink color remains for at least 30 seconds. Record how much 0.2N NaOH is left in the burette, measured to the bottom of the meniscus. Subtract the end reading from the start reading to determine how many milliliters of 0.2N NaOH you used (Mitchell 2009).

Use the following equation to calculate the TA expressed as g/l of malic acid:

$$TA = \text{mls of NaOH used} \times 0.536 = \text{g/l malic acid}$$

Adjusting titrateable acidity. Because malic acid is the primary organic acid found in apple juice, it is the focus of TA adjustment. Adjust the malic acid in juice so that it falls into the range of 4–8 g/l. Make the adjustment either by adding food grade malic acid or deacidifying the juice with calcium carbonate. When malic acid is in the desired range, TA can more predictably be used as a guide to adjust pH. Using the example above, a result of 1 g/l of malic acid would require you to add 20 grams of malic acid to a batch of 20 liters of juice.

Sulfites

Sulfur dioxide (SO₂) is a **sulfite** used to kill most spoilage organisms that develop in cider. However, some people are sensitive to sulfites, and therefore 10 mg/l or more of this ingredient must be listed on the label. The maximum allowable total sulfite content in cider is 300 mg/l. Juice from clean fruit or with a pH around 3.3 requires less sulfite to achieve a safe product.

Sulfites occur in either a “bound” or “free” state in cider, and total sulfite includes both these forms. Bound sulfites are attached to other

chemicals or solids in the cider such as apple pulp, microorganisms, or lees (live and dead yeast and bacteria), whereas free sulfites are unattached and therefore available to react. It is the free sulfites that are effective in preventing spoilage.

The desirable range of free sulfites prior to fermentation is 50–150 mg/l, depending on pH and fruit condition (Table 1). Do not add too much sulfite initially, because it inhibits the action of the yeast. Keep track of cumulative sulfite addition throughout the cider-making process. Use the following basic laboratory techniques to measure the amount of free and total sulfites in your cider.

Measuring sulfites.

Ripper method

The Ripper method involves titration with an iodine solution to measure both free and total sulfites, each of which are described below. All chemical reagents needed for these tests can be purchased from commercial suppliers of wine making laboratory materials.

Procedure for determining free sulfite

1. Wear proper lab attire and use precautions as described on the chemical manufacturer's label when conducting this titration.
2. Fill a titrate burette that has a metering valve with 0.005M iodine solution. Mark or record the starting level of the solution using the bottom of the meniscus.
3. In a 250 ml flask, add 25 ml of an undiluted juice sample.
4. Add 5.0 ml of 10% sulfuric acid and swirl flask to blend thoroughly.
5. Add 0.5 g iodine (starch) and swirl until the indicator dissolves.
6. Titrate the iodine solution into the juice sample, swirling constantly. As you see the blue color linger, continue to dispense the iodine solution by drops until the solution remains blue for about 10 seconds. Record the level of the iodine solution (the color will disappear rapidly, so watch it closely). Calculate the amount used in milliliters by subtracting the initial reading from the final reading.
7. Calculate the free sulfite: Milliliters of iodine solution used X 12.8 = free sulfite mg/l

Procedure for determining total sulfite

1. Wear proper lab attire and use precautions as described on the chemical manufacturer's label when conducting this titration.
2. Fill a titrate burette that has a metering valve with 0.005M iodine solution. Mark or record the starting level of the solution using the bottom of the meniscus.
3. In a 250 ml flask, add 25 ml of an undiluted juice sample.
4. Add 5 ml of 2M NaOH, lightly swirl, and let the flask sit for a timed 5 minutes.
5. Add 5.0 ml of 10% sulfuric acid and swirl flask to blend thoroughly.
6. Add 0.5 g iodine indicator (starch) and swirl until the indicator dissolves.
7. Titrate the iodine solution into the juice sample, swirling constantly. As you see the blue color linger, continue to dispense the iodine solution by drops until the solution remains blue for about 10 seconds. Record the level of the iodine solution (the color will disappear rapidly, so watch it closely). Calculate the amount used in milliliters by subtracting the initial reading from the final reading.
8. Calculate the total sulfite: Milliliters of iodine solution used X 12.8 = total sulfite mg/l.

Sugar and alcohol content

The sugar content of your apple juice is the determining factor for the amount of alcohol the finished cider will contain. The more sugar in the juice, the greater the alcohol content of the cider. Sugars also help add body to a cider.

Measuring sugar content. The amount of sugar in a juice is measured by specific gravity (SG), which is the ratio of the density of a liquid compared to the density of water. SG is measured with a **hydrometer** (Figure 12). Hydrometers are usually made of glass formed into a cylindrical stem attached to a weighted bulb that floats upright in liquid. Because liquid density is temperature sensitive, your juice sample must be at the temperature specified on your hydrometer before testing to obtain an accurate reading.

To measure the SG of apple juice, place approximately 80 ml of juice in a 100 ml graduated cylinder. Lower a hydrometer into

the liquid in the cylinder so that the instrument floats free. The cylinder size should be such that the hydrometer does not touch the sides or the bottom. The point at which the surface of the liquid touches the stem of the hydrometer is the SG of the juice. Juice with high sugar content will be denser, and this causes the hydrometer bulb to float higher and give a higher SG reading.

Measuring alcohol content. As stated earlier, the sugar content of your apple juice is important because it determines the amount of alcohol in the finished cider. The associated SG is used to calculate the potential percent alcohol by volume (ABV; Mitchell 2009), which should be a minimum of 6% in order for the cider to mature and resist microbial spoilage. To use SG to estimate percent ABV, assume that complete fermentation will occur and equals 1.0 (the SG of water). While hydrometer measurements are read in SG, calculations are done in gravity degrees (referred to as “gravity”). The following formula converts SG to gravity:

$$\text{Gravity} = (\text{SG} - 1.0) \times 1,000$$

To determine the percent ABV, divide the juice gravity reading by 7.5.

Example: Assuming a hydrometer reading of 1.055, subtract 1.0 to get 0.055. Multiply this number by 1,000 for the gravity of the juice (55). Assuming that complete fermentation is achieved, divide this gravity reading by 7.5 to determine percent ABV:

$$\frac{\text{Gravity}}{\text{Constant}} = \% \text{ ABV}$$

or

$$\frac{55}{7.5} = 7.14\% \text{ alcohol}$$

If you have a target ABV for your cider, calculate the gravity you will need in your juice using the following equation:

$$\text{Target alcohol value} \times 7.5 = \text{target juice gravity}$$

Adjusting sugar content. If your apple juice does not have sufficient sugar to reach your targeted cider alcohol content, you will need to add more sugar to the juice. To increase the SG of the juice, add sucrose (table sugar). For 1 liter of juice, 2.6 grams of sucrose will increase the SG by 1 degree or 0.001 on a hydrometer. Use the following equations to calculate how much sugar to add to



Figure 12. Using a hydrometer to measure the specific gravity of a juice sample.

reach your target alcohol content for the finished cider.

First, calculate the difference in gravity:

$$\text{Gravity difference} = \text{target gravity} - \text{actual gravity of juice}$$

Then, multiply the gravity difference by 2.6:

$$\text{Gravity difference} \times 2.6 \text{ grams sucrose} = \text{amount of sugar needed per liter to reach targeted \% ABV}$$

Example: The target ABV is 6.8%. If your juice SG is 1.045 but you need it to be 1.051, subtract 1.045 from 1.051, which is 0.006. Multiply by 1,000 to express this value as gravity, which equals 6. Next, multiply the gravity difference (6) by 2.6 grams (the amount of sucrose needed to raise 1 liter of juice 1 degree):

In this example, $6 \times 2.6 = 15.6$ grams of sucrose per liter.

Fermentation

After adjusting your apple juice for pH and titratable acids and adding sulfites (if applicable), allow the juice to settle for 24 hours. Next, **rack** off the juice (siphon to a new container), leaving the accumulated apple pulp sediment and debris behind. The juice is now ready for fermentation,

which can be completed using the following steps:

1. Add yeast to racked juice.
2. Add nutrients after fermentation starts.
3. Maintain the fermenting juice at 60°F (16°C) or lower to retain fruit aromas and effectiveness. Check for the optimum fermentation temperature range on each strain of yeast.
4. Expect the fermentation process to take 10 days to no more than 4 weeks. However, if you are producing large volumes of cider or require a shorter fermentation time, increase the temperature to 70°F and/or add more yeast starter culture. Under these conditions, fermentation can be completed in as short as 5 days, but cider quality may be adversely affected.
5. Use a hydrometer as described above to check the SG for a sample of the cider. The SG reading should be at 1.0 or lower if fermentation is complete. Do not rely upon **refractometer** (Brix) readings to check for residual sugars during the fermentation process, because the ethanol will cause false Brix readings.

Yeast

Most cider makers use cultured yeasts, many of which are available commercially. While wild yeasts can be used, results are often variable. Each yeast adds a different characteristic during fermentation, so selection of the appropriate yeast depends on the style of cider you aim to produce. Different yeast companies can provide descriptions of what flavor characteristics a specific yeast is likely to impart.

Poor yeast management is a significant cause of faults in finished cider. Select a yeast that is suited to the temperature range you are using to ferment your cider. Healthy yeast cultures will produce a clean fermentation, but sick, failing yeasts produce off flavors, unwanted aromas, and stuck fermentation, which occurs when fermentation stops and the conversion of sugar to alcohol is incomplete. This can quickly lead to spoiled cider.

While the following is the general process to follow for yeast inoculation (Figure 13), it is best to follow the specific instructions given by the manufacturer of the yeast product you are using.



Figure 13. Yeast inoculation to begin fermentation process.

1. Hydrate the dry yeast in water at a temperature of 104°F for 20 minutes. For 1 g of yeast, use 8–10 mls of water. This will ferment about 1 gallon of juice.
2. Keep the temperature of the hydrated yeast within 15°F of the juice temperature before adding it to the juice.

Add nutrients (vitamins, minerals, and amino acids) after fermentation starts, 1–3 days after yeast inoculation. This prevents the yeast from being stressed and promotes healthy yeast metabolism. Apple juice that is low in yeast-available nitrogen (YAN) will develop off flavors and be slow to ferment. A minimum YAN measurement of 100 mg/l is required for good fermentation (Merwin et al. 2008). Use a complex yeast nutrient mixture in juice with low levels of YAN. In the United States, most commercial orchard fruit has sufficient YAN, but low levels are sometimes found when using fruit from abandoned or poorly maintained orchards.

When alcoholic fermentation is complete and a layer of lees has settled on the bottom of the fermentation container, rack the cider and discard the lees. Racking helps prevent microbial

problems. If malolactic fermentation is not desired (see below), add SO₂ in the range of 20 to 50 mg/l of free SO₂. After racking, let the cider mature until it clears (2–6 months).

Maturation

After the juice has fermented and you've racked the cider, let it rest for 2–6 months to mature (Figure 14). Store the cider during this time from just above freezing (34°F or 1°C) to not above 60°F (16°C). During maturation, the cider clears from particulates settling out, and flavors are enhanced by natural chemical changes such as polymerization of polyphenols. However, preventing contamination and oxidation is a must.

The following are steps for successful maturation, each of which are detailed below:

- Prevent oxidation.
- Conduct malolactic fermentation (if desired).
- Monitor sulfite content.
- Store the cider until it is clear.



Figure 14. Cider maturing in glass carboys.

Preventing oxidation

Cider is more susceptible than wine to oxidation, which causes the formation of undesirable chemicals such as acetaldehyde, ethyl acetate, and acetic acid (vinegar). To exclude oxygen throughout the maturation period, keep containers and air-locks (P-traps) full and avoid air space.

Conducting malolactic fermentation

Malolactic fermentation (MLF) converts malic

acid in cider to lactic acid. Controlled and/or uncontrolled (spontaneous) MLF can reduce the organic acid content of apple cider to unacceptable levels, and may also produce unwanted flavor characteristics. Cider makers use MLF to lower acidity, increase mouthfeel, and change the aroma of a cider.

To initiate MLF, add malolactic bacteria (*Oenococcus oeni*) to cider. Top up barrels and tanks and ensure a moderate temperature of around 65°F (18°C). Monitor the progress and completion of MLF by using **paper chromatography**, which indicates the presence or absence of an acid but not the amount. A quantitative measure of malic acid can be obtained by **high pressure liquid chromatography** (HPLC), enzymatic analysis, or **Fourier transform infrared spectroscopy** (FTIR). These quantitative procedures are used by large winery operations and are more complex and more costly than paper chromatography. However, some wine laboratories conduct quantitative analyses of cider samples. For more detailed information on all these methods, refer to the glossary, Iland et al. (1993), and Zoecklein et al. (1995).

To prevent MLF, maintain free SO₂ above 20 mg/l, add sulfites as needed to base cider as discussed in the Ripper method section above, and store at 60°F (16°C) or cooler. Another option is to add lysozyme in the range of 250–500 parts per million (0.94–1.1 grams per gallon of cider). Lysozyme breaks down the cell walls of gram-positive bacteria (which can cause spoilage), thus preventing MLF. Lysozyme does not impact yeast or gram-negative bacteria (which can be beneficial). Lysozyme is manufactured from egg white and is considered an acceptable addition for organic cider makers to stop MLF; however, cider makers should check with their organic certifier before choosing a particular lysozyme product to make sure it is allowable.

Monitoring sulfite content

Measure the sulfite content of stored cider once a month to ensure that it is from 20 to 40 mg/l free SO₂ (depending on pH) to avoid microbial contamination problems. Follow the Ripper method to determine if you need to add sulfites at this stage. For low pH ciders, less sulfite will be needed. If you are using malolactic fermentation, measure and adjust sulfites after the malolactic fermentation is complete. When the cider is clear

and there are no flavor defects, you have a base cider.

Processing Base Cider

When your cider has completed the maturation process, it can be either drunk as is or processed. A base cider is dry (no fermentable sugars remain in the cider) and can be bottled and drunk as such. Bittersweet base cider is often referred to as “scrumpy,” particularly if it is unfiltered. Currently in the United States, most cider is not marketed in this form and instead is processed in various ways to create a more complex product. Some examples are combining with different apple juice varieties, barrel aging, and adding carbonation, sugar, honey, raisins, or berries. This is similar to a chef combining ingredients to create appealing new flavors and textures for a meal. Processing is the stage where cider makers define their final product.

The following steps can be used to create a marketable, unique finished cider. While some steps are required, others are optional, depending on the type of cider you wish to make.

Blending

If you have several distinctly different base ciders, you have the ingredients to make a complex cider blend. Varying proportions creates additional possibilities. Conduct sensory and market tests to evaluate consumer preferences and marketability.

Barrel aging

Aging a base or blended cider in an oak barrel (Figure 15) can add complexity and produce a distinctive cider product. The aging process can take from 3 to 4 months. Using barrels that previously contained aged spirits such as whiskey or rum can add further complexity to the cider. Another option is to place oak chips or staves in less expensive high density polyethylene barrels to provide vanilla or oak tannin flavors.

Carbonating

Carbonation can be achieved either by limited yeast fermentation after bottling (the traditional Champagne method) or injecting compressed food grade carbon dioxide (CO₂) in a **bright tank** under pressure; in small quantities it can be done with **Cornelius kegs**. Carbonation



Figure 15. Barrel aging after fermentation.

produces spritz (bubbles) and a little acidity, which adds to the aromatic intensity and mouthfeel of the cider.

Carbon dioxide is absorbed better at low temperatures, so you should cool your cider to 30–36°F before carbonating. Also make sure all the air is replaced with carbon dioxide so that oxidation does not occur. Carefully monitor and control the carbonation time and pressure.

Home cider makers use sugar priming for carbonation. A small, carefully measured amount of sugar is added to the cider just before bottling. A guide for sugar priming is about 4.0 g/l, which should produce about 1.0 **atmospheric pressure** (1.0 **bar**). Extreme care must be taken 1) not to over-prime and 2) to select sturdy bottles (preferably champagne type, which are rated for 6.0 bars), as the pressure generated by the carbonation is potentially explosive (Mitchell 2007). Do not exceed the maximum pressure that a given bottle can safely contain (see bottle specifications). Before adding sugar for priming, make sure you know whether the cider contains any fermentable sugar. To achieve the priming you need live yeast, so do not add additional sulfite to the cider after fermentation. Ciders with CO₂ and live yeast in the bottle do not need SO₂ to protect against oxidation. The live yeasts will scavenge any oxygen that might be introduced during the bottling process.

Commercial cider production has legal requirements for adding carbonation that affect the tax bracket of the final product. For details, see Alcohol and Tobacco Tax and Trade Bureau (2010).

Sweetening

Sweeteners can be added before bottling to balance a base cider, particularly if it is sharp. Many consumers expect a sweet beverage when they try cider for the first time. Adding a sweetener to some of your products may increase the sales appeal for this consumer group. There are several types and ways to add sweeteners, and several products that can be developed using each type of sweetener. Conduct marketing tests with your targeted consumers to evaluate different sweetening rates and methods and determine which are preferred.

Fresh or concentrated apple juice, sugar, honey, and other fruit juices such as raspberry, either fresh or concentrated, can be used to sweeten cider and add other fruit aromas to the final blend. Even more critical is to pasteurize or sterile filter your cider if you add fresh juice after fermenting to 1) destroy pathogenic *Escherichia coli* and 2) prevent unwanted fermentation from reoccurring in the bottle and causing it to explode.

Filtering

Most ciders are filtered to make a clear, bright product and prevent sediment in the bottle. There are many good, inexpensive filters on the market, so check with your supplier for options that best suit your needs. Sterile filtration involves running cider through a filter that has very small pores that prevent yeast from filtering through. Take care to prevent contamination between filtering the cider and capping the bottle. Most cider operations use a coarser and less expensive filtration system and then do in-bottle pasteurization to prevent refermentation in the bottle.

Bottling

Select a bottle that is appropriate for your processing style (high pressure bottles are needed if carbonation is done), target price range, and consumer preferences. Cider can be moved from bulk tanks to a bottler by gravity, pump, CO₂ pressure, or siphon flow. If a cider is carbonated, it moves naturally by pressure from the bright tank to the bottler. Filling bottles with carbonated cider requires a counter pressure filler (Figure 16) to prevent the product from foaming out. Most companies pasteurize after bottling because this procedure usually



Figure 16. Commercial counter pressure bottle filling machine.

prevents microbial contamination (see In-bottle pasteurization, below).

Pasteurizing

Pasteurization is the process of heating a liquid to destroy undesirable microorganisms and neutralize nonfermented sugar to prevent refermentation in bottles. Fermentable sugar in bottles is not only a safety hazard due to potential explosion of the bottles, but results in haze, sediment, and undesirable aromas. Cider that does not have fermentable sugar also benefits from pasteurization because the process preserves quality.

There are several types of pasteurization processes you can use for cider, and each has distinct attributes. To help you decide which type of pasteurization is most appropriate for your cider, consider that the potential for contamination is created whenever you 1) move cider to a different container and 2) add sweeteners into cider. No matter what type of pasteurization you choose, wear the proper safety attire, which includes

a face shield, long-sleeved shirt or lab coat, and heat-resistant gloves.

In-bottle pasteurization. Pasteurizing cider in the bottle you will sell it in is the most common method used in cider making because it is also the safest. In-bottle pasteurization eliminates fermentation and microorganism problems within the bottle, prevents recontamination because the bottle is sealed, and can enhance the final product.

To conduct in-bottle pasteurization, select a bottle and cap that can withstand the heat and pressure of pasteurization. Corks tend to blow out, so use crown or screw caps. For large-scale operations, choose a tunnel pasteurizer. On a small scale, select an apparatus such as a water bath pasteurizer or a turkey cooker, as long as it provides uniform accurate temperature control (Figure 17). Monitor bottles for temperature and leaks to ensure they were not damaged by the process.

Flash pasteurization. To conduct flash pasteurization, run your cider through the pasteurizer, which consists of a small tube that heats the liquid very rapidly to a temperature sufficient for pasteurizing. Immediately bottle, cap, and cool the cider to prevent contamination.

Completed before fermentation, flash pasteurization will reduce potential contamination during the fermentation process, and so is especially useful when making cider without sulfites. You can also conduct flash pasteurization after maturation as you fill the cider into bottles. However, unless you use aseptic bottling procedures, there is a risk of recontamination which can cause the cider to referment and the bottle to explode.

Calculating pasteurization units (PUs). Calculating PUs is a function of time and temperature, with PUs increasing exponentially per minute with each degree above 60°C. Pasteurization must achieve the proper temperature and length of time to be effective. Calculate the PUs needed with the following equation (Mitchell 2008):

$$PU = T (\text{time}) \times 1.393^{(\text{Temperature } ^\circ\text{C} - 60^\circ\text{C})}$$

Example: To reach a bottle temperature of 62°C, calculate the time needed to obtain 50 PUs:

$$50 \text{ PU} = T \times 1.393^{(62-60)}$$

$$50 \text{ PU} = T \times 1.393^{(2)}$$

$$50 \text{ PU} = T \times 1.94$$

Divide both sides by 1.94 and T = 25.8 minutes



Figure 17. Home pasteurization. For small-scale operations, a propane-heated water bath with accurate temperature control can be used (left). Be sure to wear protective clothing (right) during this procedure.

Note that PUs accumulate from the time a cider reaches 60°C until it reaches 62°C, and when the temperature drops from 62°C to 60°C.

Heat clear fermented ciders to obtain 50 PUs, which is usually more than enough time and heat to produce a safe, sterile, and stable cider. To achieve the same effect for fresh juice, heat up to 3,500 PUs because of the higher load of microorganisms and suspended particles.

Use a properly calibrated, heat-stable thermometer and place it in an unsealed cider bottle filled with water to monitor pasteurizing temperature. Make sure the water is as cold or colder than the cider. Do not pasteurize juice or cider above 65°C; otherwise, the end product may have an unpleasant cooked flavor. Check the cider temperature in the monitoring bottle for every batch to ensure that the procedure worked correctly.

Safety testing

To ensure that your cider is safe to consume, send pasteurized sample bottles to a commercial laboratory for testing. The total viable count of microorganisms should be zero and the SO₂ content should be below the maximum allowable 300 mg/l. Check with other cideries or wineries in your area to see where they safety test their products, or if they will test outside products.

Evaluating

The final step before putting your cider on the market is assessing its quality to ensure that it meets consumer expectations, especially during the initial years of product development and marketing. Include as many evaluators as possible to gain thorough descriptive results. However, do not over-describe the cider or create characteristics that are not actually present. A table of standardized cider flavor descriptors, similar to those developed for beer and wine, is available at <http://www.cider.org.uk/flavour.htm> (Lea 1999).

PART II: BASIC CIDER ORCHARD MANAGEMENT

Managing a cider orchard is essentially the same as managing a dessert apple orchard. We will provide an overview of management needs and techniques, but for more detailed information, refer to Cogger (2005), Grove and Xia (2005),

Moulton (1995 and 1996), Peters et al. (2010), Righetti et al. (1998), Stebbins (2003), and Washington State University Extension (2010).

Whether you have an existing orchard of dessert apple varieties and use the culls to make cider or are growing apples specifically for cider, the key point to remember is that apples used for premium cider must have good internal quality; that is, they must be fully ripe and free of rot and other damage. External blemishes such as mildew, russet, or mild apple scab lesions are of little consequence in cider production. A key to ensuring good quality fruit for cider making is to harvest only fruit that is fully ripe. Trees that have too high a fruit load, or leaves that are unhealthy (somewhat yellowed or diseased) can have poor internal fruit quality. See the sections on thinning and pest management (pp. 32 and 33, respectively) for more information regarding these issues.

Sites and Soils

The first issues to consider for a successful cider orchard are site selection and soil analysis. Apply the following basic principles:

- Maximize sun exposure.
- Ensure good airflow across the entire orchard.
- Choose well-drained soils.
- Determine soil types by sampling.
- Apply soil amendments before planting whenever possible.

Soil quality

Good soil and plant nutrition are essential to good internal fruit quality. Soil must be well drained and properly amended to accommodate the nutritional needs of apple trees. Cogger (2005) is a good reference for basic concepts on soil nutrition, fertility, and pH, while Righetti et al. (1998) outlines soil nutrient considerations for commercial orchards based on research in Oregon, and Colt et al. (2001) includes both crop information and cultural practices for Idaho. In western Washington, where limited apple production research has been conducted, guidelines for nutritional amendments based on research from New York (Stiles and Reid 1991) have been very effective; Table 4 shows recommended guidelines for each element and preferred concentrations in the soil.

Table 4. Soil fertility guidelines (adapted from Stiles and Reed 1991).

Element	Preplant	Established Orchard
Ca (calcium)	67% CEC	58% CEC
Mg (magnesium)	13% CEC	12% CEC
K (potassium)	200 + ppm	200 + ppm
P (phosphorus)	At least 40 ppm	At least 40 ppm
B (boron)	1–2 ppm	1–2 ppm
Zn (zinc)	2 ppm	2 ppm
Cu (copper)	2 ppm	2 ppm
Mn (manganese)	5 ppm	5 ppm

Soil sampling. Collect two soil sample types, one that includes topsoil from the upper 0-8 inches, and the second from the subsoil, 8-16 inches deep; use a different bucket for each type. Gather 5–6 samples of both topsoil and subsoil from different areas of your orchard. In each bucket, mix the samples together until well blended and send 1–2 cups (depending on instructions from the testing laboratory) for analysis. For a list of testing laboratories in the region, refer to Washington State Pest Management Resource Service (2009). If your orchard has several distinct soil types, send in separate samples for each area.

Consult your local Extension office or a commercial fertilizer supplier to help you interpret the results of your soil analysis and decide on any needed amendments. Incorporate any soil amendments before planting when it is much easier to do so.

Orchard Layout

Prepare for planting by lining out tree rows that run north-south to provide the best sun exposure. If your orchard is in an area where temperatures often exceed 90°F, sunburn could be a serious problem, so lay rows out ENE to WSW for maximum exposure to the cool morning sun.

As a general rule, space your rows according to the final (or estimated) height of the mature trees. For instance, plant an 8-foot-tall tree in rows spaced 8 feet apart. However, the use of machines for mowing, spraying, or harvest may require wider spacing. Refer to the rootstock information below to determine minimum and maximum row and in-row spacing. Align the trees as closely as the site allows. If you are considering mechanical harvest, remember that

orchard topography, spacing, and trellis systems will need to accommodate harvest equipment.

Rootstock Selection

Choose good quality plants for starting your orchard—weak trees are no bargain in the long term. Wherever possible, obtain certified virus-free stock for planting. Consider both your fruit harvest method and that apple varieties differ in plant vigor. When grafted on the same rootstock, the more vigorous varieties result in larger trees, while less vigorous varieties result in smaller trees (Figures 18 and 19 and Table 5).

If you plan to handpick your apples, choose an orchard that requires little or no use of ladders, such as trees grafted on M9 or even smaller rootstock. You will need to include a trellis system to support the trees and their fruit load. Smaller rootstock also enables you to plant more trees per acre to attain maximum yield. Smaller trees are more efficient producers and

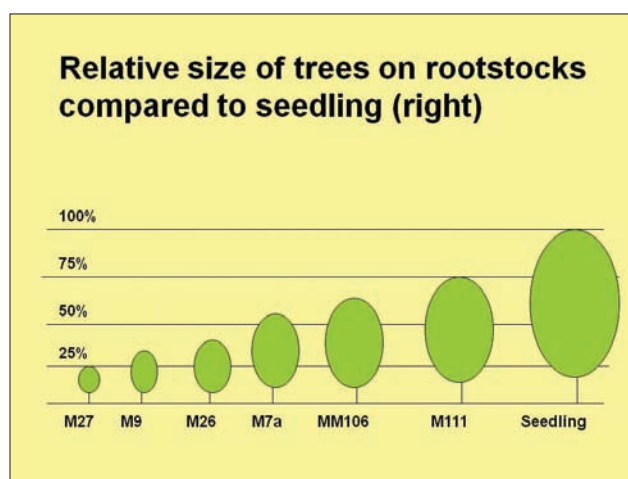


Figure 18. Relative tree size of select apple rootstocks.

Figure 19. Trees of the same age grafted on different rootstocks: Brookfield Gala grafted on M9 (left) and Yarlington Mill grafted on M106 (right).



Table 5. Apple rootstock effects on tree height, support needs, and spacing needed between trees.

Rootstock	Habit	Height at Maturity (feet)	Support Systems	Spacing between Trees (feet)
M 27	Extreme dwarfing	6–9	Espalier, trellis, patio pots	3–5
Bud 9 ¹ and M 9	Strongly dwarfing	8–10	Espalier, trellis, large pots, post or wire	4–6
M 26	Semi-dwarf	10–14	Early support on post	6–10
M 7	Somewhat dwarfing	12–18	Mostly free standing, but some varieties lean	8–12
M 106 ²	Somewhat dwarfing	12–18	Free standing, well anchored	8–12
M 111	Somewhat dwarfing	14–22	Free standing, well anchored	10–14

¹Bud 9 preferred for sites with very cold winters and fire-blight problems.

²Avoid poorly drained soils as susceptible to crown rot.

require much less pruning and chemical inputs per unit of fruit production. Another advantage of dwarfing rootstocks is that fruit ripens more uniformly and faster than larger rootstock, which means you will get an earlier return on your investment.

Alternatively, if you intend to harvest with a machine, larger rootstock may be preferable. In traditional cider-producing regions such as the United Kingdom, larger rootstocks are often used in orchards so that trees can be mechanically harvested. Harvest is accomplished by shaking

the tree via a trunk shaker, so a strong rootstock and trunk are needed to sustain this process.

Variety Selection

An overview of the juice and cider characteristics of the four basic cider apple categories and several promising varieties for the Pacific Northwest is provided in Part I of this publication. The following cultural and environmental factors must also be considered when selecting a variety or multiple varieties to grow for cider:

- Bloom dates and pollination
- Harvest sequence and timing
- Resistance to diseases and pests

If you plant several varieties, factor in their various maturity dates so that you can feasibly harvest and process the juice from all the trees in your orchard. Early cider varieties ripen in late August and often do not store well, thus may not be useful for small cider makers who do not have cold storage facilities. Mid- to late-season varieties generally produce superior quality ciders (Lea 2008) and, as with dessert apples, store better (see p. 5, Characteristics of varietal ciders, for detailed information). You will need to consider growth habit and fruit size if you grow specialty cider apples. Several of the traditional cider varieties used in the United Kingdom have exhibited problems (e.g., high vigor, excessive blind wood, and alternate bearing) in American orchards (Merwin et al. 2008). Table 6 describes some of the cider varieties from trials at the WSU Mount Vernon NWREC with respect to tree habit, productivity, grower friendliness, and tendency to alternate bearing.

Pollinizers

Pollinizer varieties bloom at the same time as the primary crop variety to assure good fruit set. Plant one pollinizer tree every 50 feet in your cider orchard, either as a separate row or interspersed with cider varieties. Ideally the pollinizer can also be used for cider. Crabapples are often used as pollinizers because of their profuse bloom, and as discussed in Part I, they are also suitable for blended cider. If you don't intend to harvest the fruit, train the pollinizer trees to a narrow upright habit that takes up less orchard space. Bloom dates for your pollinizers must overlap with those for your cider varieties (see Table 7).

Irrigation

Irrigation is almost essential in all areas for trees of any age on dwarfing rootstocks. In the maritime Pacific Northwest, irrigation is primarily supplemental for mature orchards on more vigorous rootstocks. Depending on soil conditions, irrigation may not be needed for deep rooted trees once they are well established, unless sited in a rain shadow area. As fall approaches (late August), reduce irrigation to encourage trees to set terminal buds. If there is no rainfall after terminal buds set, apply irrigation selectively to maintain tree health.

Install an irrigation system at planting so young trees become well established. If you are planting in an area with high winter and spring rainfall and a high water table, consider installing drain tiles in each row for more rapid drainage. Do not allow trees to experience drought stress (as determined by tensiometer readings, described below, and soil type) during the year of planting or early in the growing season every year. Early stress can stop the growth of new shoots. In addition, uptake of potassium that is essential for good internal fruit quality can be severely inhibited when trees are water stressed.

Many orchards in the Pacific Northwest use drip irrigation (Figure 20). Use a **tensiometer** or some other soil moisture test to determine when to irrigate. Install the tensiometer within 12 inches of an emitter and between 6 and 12 inches deep to monitor soil moisture in the upper level of the soil profile. Most of the water and nutrient uptake occurs at this depth, particularly for dwarf trees. Locate the tensiometer in the area of the orchard with the sandiest and driest soil, and irrigate based on these readings so that none of the trees are moisture stressed. Where there are wide variations in soil types, additional tensiometer stations may be needed.

Consult your local Extension office for irrigation recommendations in your area and/or see Peters et al. (2010) for more information on irrigation systems, deep irrigation, and monitoring soil moisture.

Pruning

One of the basic functions of pruning for cider apple trees is to promote light penetration for good internal fruit quality and complete

Table 6. Tree growth habit and tree characteristics of cider apple varieties observed at the WSU Mount Vernon NWREC.

GROWTH HABIT & CHARACTERISTICS											
Cultivar	Spur	Semi-Spur	Standard	Tip Bearer	Blind Wood ¹	Spreading	Upright	Grower Friendly ²	Alternate Bearing ³	Productivity ⁴	Comments
Amere de Berthecourt		X			1.5	X		Y	Y	Good	Mid bloomer, blooms with Gala
American Forestier ⁵		X			1			Y		Good	
Blanc Mollet ⁵		X			1.5		Semi	Y		Good	
Bouteville			X		1.5	Semi		Semi		Good	
Bramley's Seedling			X		2.5	X		Y	Semi	Good	
Breakwell Seedling		X			1	X		Y	N	Good	Appears grower friendly due to shape, try on M9
Brown's Apple		X			2	Semi		Y	Y	Good	
Brown Snout	X				1	Semi		Y	N	Good	Small fruit, but consistent
Brown Thorn ⁵			X		2		Semi	Semi		Fair	Vigorous
Bulmer's Norman		X			1	X		Y	Y	Good	
Campfield ⁵		X			2		X	Semi		Fair	
Cap O' Liberty	X				1		Semi	Y	Y	Good	
Cimetiere		X			1			Y	Y	Poor/ Good	
Coat Jersey		X			2.5	X		Y	Y	Poor/ Fair	
Court Pendu Plat		X			1.5		Semi	Semi		Fair	Weak grower
Court Pendu Rose		X			1.5	X		Y		Fair	Weak growth
Crow Egg		X			2	X		Y	Y	Fair to Good	
Dabinett		X			1.5	X		Y	N	Good	Consistent nice fruit
Finkenwerder Herbstprinz				X	2.5	Semi		Semi	N	Fair	
Frequin Audievre ⁵		X			1		Semi	Y		Good	Looks promising
Frequin Rouge		X		X	1.5	X		Y	Semi	Good	Productivity looks promising
Frequin Tardif ⁵		X			1		Semi	Y		Good	
Golden Russet			X	X	2.5	X		N	Semi	Fair	Tip bearer, harder to manage

Table 6 (continued). Tree growth habit and tree characteristics of cider apple varieties observed at the WSU Mount Vernon NWREC.

GROWTH HABIT & CHARACTERISTICS											
Cultivar	Spur	Semi-Spur	Standard	Tip Bearer	Blind Wood ¹	Spreading	Upright	Grower Friendly ²	Alternate Bearing ³	Productivity ⁴	Comments
Granniwinkle		X			2		Semi	Y		Good	
Grindstone				X	4	X		N		Poor	Productivity looks low
Harrison				X	2		X	Y	N	Fair	
Harry Masters' Jersey		X			1	X		Y	Y	Good	
Jouveaux		X			1.5		Semi	Y	N	Good	Productivity looks promising—early blooms
Kermerrien		X			1	X		Y	Y	Good	
Kingston Black			X		2	X		Y	Semi	Fair to Good	
Lambrooke Pippin ⁵			X		3.5	Semi		N		Poor	Vigor is high, productivity looks low
Major			X		1.5		Semi	Y	Y	Poor to Good	
Medaille D'Or ⁵		X			1		Semi	N		Fair	
Metais ⁵			X		2.5		Semi	Semi		Good	
Michelin		X			2		Semi	Y	Y	Good	
Muscadet de Dieppe			X	X	2.5	X		N	Y	Poor to Fair	Good quality, but not productive
Muscat de Bernay		X			2		Semi	Y		Good	
Peau de Vache		X			1	X		Y	N	Good	
Red Jersey ⁵			X		1.5	X		Semi	Y	Poor to Good	
Redstreak			X	X	2.5	X		Y	Semi	Good	
Reine des Pommes		X			3		X	Semi	Y	Fair	
Royal Jersey ⁵		X			1		Semi	Y		Good	
Roxbury Russet				X	3.5		Semi	N	N	Fair	
Smith's Cider ⁵		X			2		Semi	Y		Good	Productivity has good potential
Sweet Alford		X			1	X		Y	Semi	Fair	Productivity looks promising

Table 6 (continued). Tree growth habit and tree characteristics of cider apple varieties observed at the WSU Mount Vernon NWREC.

Cultivar	GROWTH HABIT & CHARACTERISTICS										Comments
	Spur	Semi-Spur	Standard	Tip Bearer	Blind Wood ¹	Spreading	Upright	Grower Friendly ²	Alternate Bearing ³	Productivity ⁴	
Sweet Coppin		X			2	X		Semi		Good	Vigorous
Taylor's		X			2.5	X		Y		Good	
Tom Putt		X			2	X		Y	Semi	Good	Drops fruit
Track Zero Seedling		X			1	X		Y	Semi	Good	Flowers heavily on 1 year wood
Vilberie		X			2	X		Y	Y	Good	
Whidbey		X			2.5	X		Y		Poor	
Yarlington Mill			X		2	X		Y	Y	Good	
Zabergau Reinette ⁵		X			2	Semi		Y		Fair	

¹Blind wood: 1—None to few areas (less than 4 inches), 2—Few bare areas (most between 4 and 6 inches with no bud break), 3—Several bare areas between 4 and 6 inches with no bud break, 4—Several bare areas less than 1 foot but most longer than 8 inches with no bud break, 5—Several areas on numerous branches with 1 foot or longer having no bud break.
²Grower Friendly: A tree that is productive and does not require extensive in-field manipulation (labor) of the canopy; tip bearers require more canopy manipulation; willow trees may require tying and more pruning labor; spur types are grower friendly, usually have stiffer wood and hold their crop load well, but they can also have a tendency to alternate bearing.
³Alternate Bearing: Blank space indicates insufficient observations to determine.
⁴Productivity (field observations): Good—Yields heavily (commercial quantity of fruit), Fair—Yields moderate quantity of fruit, Poor—Yields low quantity of fruit.
⁵Year 1 data only, young trees; not all data are complete.

Table 7. Mean date (month and day) of full bloom in cider apple cultivars observed at the WSU Mount Vernon NWREC, 2000-2009, listed in order from earliest to latest bloomers. Data was not collected in 2005 or 2006, and blank cells indicate varieties were not available for observation.

Cultivar	Mean Date	2009	2008	2007	2004	2003	2002	2001	2000
Golden Russet	5/3	5/13	5/10	4/30	4/14	5/6			
Roxbury Russet	5/3	5/7	5/10	4/28	4/16	5/6	5/15	5/2	4/28
Track Zero Seedling	5/5	5/7	5/9	4/28					
Granniwinkle	5/6	5/7	5/5						
Tom Putt	5/6	5/13	5/16	5/7	4/23	5/13			
Grimes Golden	5/7	5/7							
Grindstone	5/7	5/7	5/7						
Jouveaux	5/7	5/7	5/7						
Maude	5/7	5/7							
Muscat de Bernay	5/7	5/7							
Reine des Pommes	5/7	5/13		5/7	4/23	5/13			
Bramley's Seedling	5/8	5/13	5/16	5/7	4/23	5/11			
Foxwhelp	5/8			5/7	4/23	5/13	5/15	5/9	5/11
Redstreak	5/8	5/13	5/16	5/7	4/26				
Brown's Apple	5/8				4/23	5/13	5/15	5/16	
Smith's Cider	5/9	5/9							
Bouteville	5/9	5/7	5/13						
Cap O' Liberty	5/10	5/7	5/16	5/7					
Frequin Rouge	5/10	5/7	5/16	5/7					
Tremlett's Bitter	5/10	5/7	5/16	5/7					
Bulmer's Norman	5/10	5/13	5/16	5/7	4/28	5/19			
Sweet Alford	5/11	5/7	5/16						
Crow Egg	5/11	5/7	5/16						
Michelin	5/12	5/15	5/18	5/7	4/25	5/13	5/21	5/16	
Muscadet de Dieppe	5/12	5/13	5/18	5/7	4/28	5/13	5/21	5/16	5/11
Reine des Hatives	5/12	5/13	5/18	5/5					
Taylor's	5/12	5/13						5/11	5/11
Zabergau Reinette	5/12	5/7	5/16						
Bramtot	5/12	5/13							
Campfield	5/13	5/13							
Doux Normandie	5/13	5/13							
Fillbarrel	5/13	5/13							
Finkenwerder Herbstprinz	5/13	5/13	5/18	5/7					
Kingston Black	5/13	5/19	5/25	5/7	4/25	5/13	5/21		
Metais	5/13	5/13							
Stembridge Jersey	5/13	5/13							
Vagner Ascher	5/13	5/13							
Amere de Berthcourt	5/15	5/15							
Kermerrien	5/15	5/13	5/16	5/15					
Taliaferro	5/15	5/13	5/16						
Whidbey	5/15	5/13	5/16						
Chisel Jersey	5/16	5/19	5/18	5/15	4/30	5/19	5/21	5/19	
Harrison	5/16	5/13	5/18						
Yarlington Mill	5/17	5/13	5/18	5/15	4/30	5/19	5/21	5/19	5/11

Table 7 (continued). Mean date (month and day) of full bloom in cider apple cultivars observed at the WSU Mount Vernon NWREC, 2000-2009, listed in order from earliest to latest bloomers. Data was not collected in 2005 or 2006, and blank cells indicate varieties were not available for observation.

Cultivar	Mean Date	2009	2008	2007	2004	2003	2002	2001	2000
Dabinett	5/18	5/19	5/25	5/17	5/3	5/22	5/21	5/17	
Harry Masters' Jersey	5/18	5/19	5/30	5/15	5/3	5/19	5/21	5/19	
Major	5/18	5/19	5/16						
American Forester	5/18	5/19							
Blanc Mollet	5/19	5/19							
Brown Thorn	5/19	5/19							
Coat Jersey	5/19	5/19	5/18						
Frequin Audievre	5/19	5/19							
Frequin Tardif	5/19	5/19							
Lambrooke Pippin	5/19	5/19							
Peau de Vache	5/19	5/19	5/18						
Sweet Coppin	5/19	5/19							
Royal Jersey	5/21	5/21							
Brown Snout	5/23	5/27		5/22	5/4	5/22	5/31	5/29	
Breakwell Seedling	5/24	5/27	5/22	5/22					
Vilberie	5/24	5/27	5/30	5/22	5/4	5/22	5/31	5/29	
Court Pendu Plat	5/25	5/19	5/30						
Court Pendu Rose	5/25	5/19	5/30						
Red Jersey	5/25		5/25						
Cimitiere	5/29	5/27	5/30						
Medaille D'Or	5/29	5/29							

ripeness. The side branches coming off the leader should diminish in diameter as you go up the central leader. Any side branch in the upper part of the tree with a diameter that is more than half the central leader's diameter should be pruned out, and a weaker side branch kept instead. This allows more light penetration into the rest of the tree.

Additional pruning objectives are maintaining a good central leader with fruitful side branches and regulating the crop to reduce alternate bearing (discussed below). In a year when the tree produces a large crop, prune lighter that winter. In a year when the tree produces a smaller crop, prune harder. To further minimize alternate bearing, thin fruit early in the season (see Thinning, below). See Moulton (1996) and Stebbins (2003) for more detailed pruning instructions.

Thinning

Biennial or alternate bearing can be a serious

problem for the cider apple grower. Alternate bearing refers to a large crop one year (the "on" year), followed by a small crop the following year (the "off" year). Newly set fruits contain immature seeds that generate **gibberellins** (plant hormones) which inhibit the formation of new fruit buds, a process occurring in late spring until early summer. Too high a concentration of gibberellins can drastically reduce fruit bud formation for the following year. In a year with a light crop, less of the hormone is produced during bud formation, and thus a massive or "snowball" bloom can result the following year. Alternating heavy and light fruit sets initiates a cycle of alternate bearing. Varieties differ in their susceptibility to alternate bearing, and trees on dwarfing rootstocks in maritime climates like western Washington and Oregon seem to be less susceptible than those on larger rootstocks.

To reduce alternate bearing and the fruit load on cider apple trees, thin either at flowering or before seeds are set in the fruit. Apples usually set most of next year's fruit buds within six



Figure 20. Drip lines for irrigation in a young orchard.

weeks of full bloom, so the earlier you thin, the more impact you have on alternate bearing and fruit quality. Thinning improves fruit quality by balancing the leaf-to-fruit ratio, and also reduces preharvest drop from “push-offs” (when too many fruit set on a single spur). Although you can thin blooms and fruit by hand, this may be too costly for a cider operation. If you use chemical bloom thinners, start early and be aggressive to avoid the need for a follow-up fruit thinning.

Another method of reducing alternate bearing is to add nitrogen after trees set terminal buds (late August). Do not add nitrogen if leaf and soil samples show that the tree or the soil is already nitrogen-rich.

Pest Management

If you manage an orchard solely for cider production, a good pest control program is important. However, some pest issues can be tolerated at low levels. For example, external blemishes such as mildew, russet, or mild apple scab lesions are of little importance so long as internal fruit quality is good. To maintain a healthy, productive orchard, use preventive measures to protect trees from the primary pests that occur throughout the region. The following

is a general calendar for pest management:

- Late winter to early spring—**apple scab** delayed dormant spray, **apple anthracnose** monitoring and control, weed control
- Spring to early summer—weed control, fire blight (in affected areas), codling moth and apple maggot control
- Late summer—insect monitoring and apple maggot control
- Postharvest to winter—anthracnose monitoring and control

The most critical elements of a successful pest management program are to identify 1) which pests are most problematic in your area, and 2) the window of time when each pest is most likely to occur. Even the most effective pesticide is of little value if not applied at the correct time. Pest management is usually most effective when applied at the earliest stages of the infestation, as this controls or represses both the primary and secondary insect or disease infections.

Most pest management for apple orchards is timed to match a certain tree growth stage. For a bud development chart of bloom stages and timing of applications, see Washington State University Extension (2010); other similar regional information is available at Oregon State University (2010) and University of Idaho Extension (2010).

As an example, apple scab infections start at Stage 2-3 (delayed dormant, ¼-inch green tip) when **ascospores** are being ejected from **ascocarps** on old leaves on the ground. The determining factors for infection are moisture (leaf wetness) and temperature over time. In the maritime Pacific Northwest, moisture and temperature conditions are such that in most years, disease management sprays should be applied for at least 8 weeks starting at Stage 3 (green tip). After that time, disease pressure remains low for the rest of the year.

If you are unable to spray early and a leaf or fruit infection takes place, conidia (another type of spore) will continue to be produced for the rest of the season. Disease pressure will remain for the rest of the year, and several more sprays will be needed. In such a case, control is minimal at best, because this type of spore infects more rapidly.

It is also worth considering that the polyphenols in bittersweet and bittersharp varieties make

these fruits naturally more resistant to diseases such as scab. However, this does not apply to diseases that attack plant parts other than fruit (Merwin et al. 2008).

Another complicating factor is that several bittersweet and bittersharp varieties bloom when the weather is warmer and fire blight pressure is highest. There is no easy solution to a **fire blight** infection; affected limbs should be cut out and burned as soon as the disease is noted. Check with your local Extension office to learn more about pest issues in your area.

Harvest Maturity Indicators

To determine if your apples are ready for harvest, first measure the sugar content of the fruit with a refractometer or Brix meter, which gives a reading of percent soluble solids or degrees Brix. Squeeze a few drops of juice onto the viewing plate and read the Brix number, which is the degree to which the light rays are bent (refracted) by the solids in the solution. Table 2 provides Brix readings for ripe cider apples at the WSU Mount Vernon NWREC. A hand-held pressure tester can also be used to determine apple maturity.

Next conduct a starch conversion test to determine how much of the starch in the apple cells has been converted to sugars. This test works on the principle that as the apple matures, starch in the cells is gradually converted to sugar. When a sample is cut horizontally through the core and sprayed with a dilute iodine solution, the iodine turns the cells containing starch dark, but does not color those cells containing sugar. If only the core area is clear and the rest of the cross section is dark, the fruit is immature (Figure 21). If most or all of the cross section of the fruit is clear, it is fully ripe. Pre-mixed iodine solution for testing can be ordered from orchard suppliers. *Remember that iodine is poisonous, so be sure to discard tested apples safely (e.g., in a designated landfill rather than your orchard).*

Harvest Methods

Harvest cider apples at peak ripeness (Stages 8 and 9 in Figure 21). When apples start to fall, collect ground-falls, then go around the tree once and pick fruit that look similar in ripeness (color) to the ground-falls. Shaking the tree slightly will cause ripe fruit to fall. Harvest all ripe fruit, then wait a week and harvest the next batch the

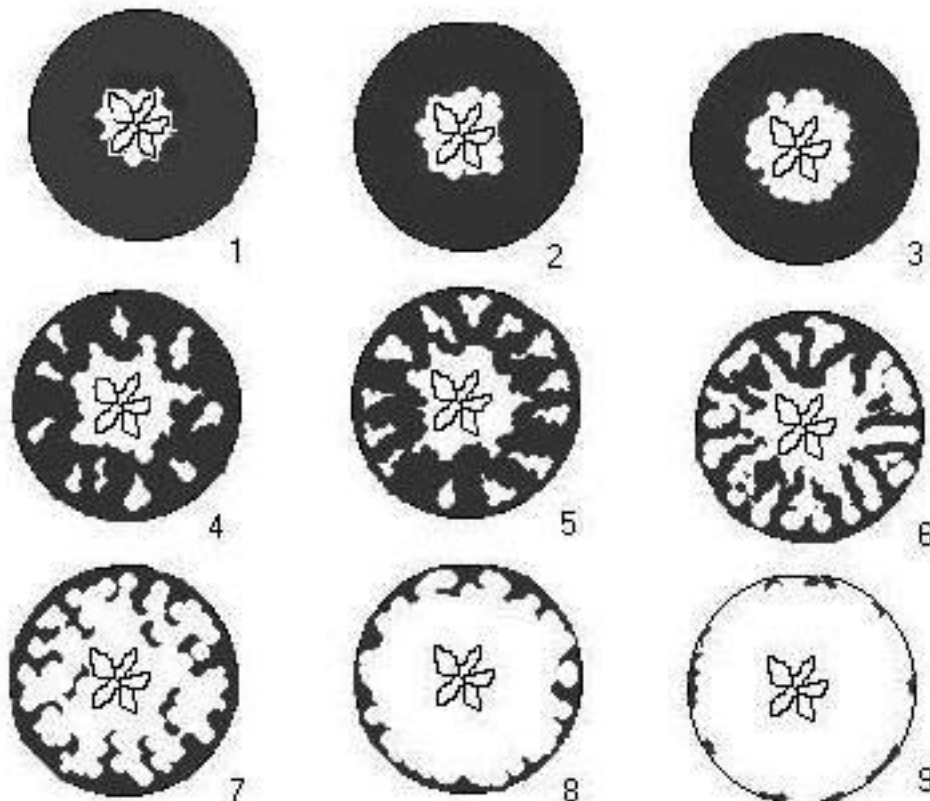


Figure 21. Starch test indicators where 1, 2, 3 = Unripe; 4, 5 = Suitable for long storage; 6, 7 = Suitable for short storage (up to 3 months); and 8, 9 = Tree ripe, store less than 1 month (adapted from Chu and Wilson 2000).

same way. Repeat harvesting as many times as the weather permits. Do not use rotting fruits, as they will impart off flavors and add spoilage microorganisms to the cider.

Some growers apply a “stop drop” spray to hold fruit on trees, then harvest all the fruit with one picking. Although less time-consuming, this method results in mixing some starchy, less ripe fruit with fully ripe fruit. Large growers in England use tractor-mounted tree shakers, air blowers, and mechanical brushes to sweep up fruit from orchard alleyways. This can cause fruit damage, but a small amount of bruising is usually acceptable if fruit is used soon after harvest.

In a study at the WSU Mount Vernon NWREC, we trained and maintained a narrow-wall cider planting and harvested fruit with a raspberry harvester (Littau Over-Row Harvester, Model OR0012, Stayton, OR). Although this production and harvest system is in the preliminary stages of development, we found that it works well with small-fruited varieties (e.g., one 20-bushel bin in 15 minutes) that can be costly to pick by hand (Figure 22). With some modification, such a mechanical harvest system might be suitable for small trees. With further adjustments, the machine could also possibly be used for other operations such as spraying, pruning, and fruit thinning.

Storage

It is traditionally considered necessary to store apples up to one month after harvest for uniform ripening, which is referred to as **sweating**. The primary purpose of sweating is to ensure that as much starch as possible in the fruit is converted into sugar. Changes in flavor precursors also probably occur (Lea 2008). Carefully monitor stored fruit for rot and discard rotten fruit.

Apples can also be put into cold storage for maturation. However, soluble pectin is produced as the fruit is stored, which may eventually cause sliminess when the apples are pressed. Varieties differ in the length of time they retain good quality in storage. For example, Dabinett can generally be stored for 4-6 months. Certain varieties such as Harry Masters' Jersey tend to develop water core, which shortens their storage life to 1-2 months (Mattheis 1998).



Figure 22. Trial of machine harvesting cider apples (variety Brown Snout) with a raspberry picker.

Monitor all stored fruit for rot, breakdown, and flavor; mill and press fruit before problems arise so that you can process as much ripe, quality fruit as possible to minimize loss. With experience, you will be able to determine how long each variety can be stored under the conditions on your farm. As a grower and cider maker, you will need to balance harvest efficiency and labor costs with ripeness and desired fruit quality, always keeping in mind your end product.

CONCLUSION

The best way to learn good cider making and orchard management practices is to start doing it. Produce some test batches on a small scale, and taste and share your information and ciders with friends and colleagues. Enter competitions to get some useful critiques from judges. Many cider makers say that as they progressed from small batches to big batches their work got easier, and much of what they learned was from those early cider batches. Mastering the art of making cider is a broad and engaging field and one that always leaves room for improvement. Each year and batch will add to your knowledge and experience.

GLOSSARY

Accumulated heat units (AHU). See Growing degree days.

Airlock (Fermentation lock). A device used in beer, wine, and cider making that allows carbon dioxide released by the fermenting liquid to escape the fermenter, while preventing air from entering the fermenter, thus avoiding oxidation.

Alcohol by volume (ABV). A standard measure of how much alcohol (ethanol) is contained in an alcoholic beverage (expressed as a percentage of total volume).

Apical dominance. The tendency of a bud located at the highest point on a branch or shoot to grow the most vigorously.

Apple anthracnose. An infectious disease caused by the fungus *Pezicula malicorticis* (*Cryptosporiopsis curvispora*) that is common in moist climate areas. Damage includes cankers on limbs that can be fatal to infected trees. Also called bull's eye rot.

Apple scab. An infectious fungus disease caused by *Venturia inaequalis* that produces lesions on fruit and can partially defoliate trees.

Ascocarps. Fruiting bodies of an ascomycete (sac-type) fungus.

Ascospores. Sexually reproduced fungal spores formed within an ascus (sexual spore-bearing cell).

Atmospheric pressure. The force per unit area exerted against a surface by the weight of the air above that surface.

Bittersharp. Category of cider apple that is high in both tannin (above 0.2%) and acid (above 0.45%), as defined by Williams (1975).

Bittersweet. Category of cider apple that is high in tannin (above 0.2%) but relatively low in acid (below 0.45%), as defined by Williams (1975).

Blind wood. Areas of a branch that are lacking in side shoots and spurs, with large unproductive areas; a characteristic of growth habit.

Bright tank. A pressure vessel in which cider is placed after primary fermentation where CO₂ is introduced and absorbed. Also called a serving tank or secondary tank.

Brix. Soluble solids or sugar content, measured as a percentage.

Carboy. Container of glass or plastic used in fermentation, usually fitted with a rubber stopper and a fermentation lock to prevent bacteria and spoiled yeast from entering during the fermentation process.

Cation exchange capacity (CEC). The sum total of exchangeable cations that a soil can adsorb; expressed in centimoles per kilogram of soil; used in interpreting soil test results.

Chaptalize. The process of adding sugar to apple juice during fermentation to increase alcohol content.

Cheese. Alternating thin layers of apple pulp and straw in a traditional cider press. The straw provides drainage channels so that when pressure is applied with screws, the juice flows over a receiving tray and into a barrel.

Conidia. Asexually produced fungal spores formed at the tip of a specialized organ in certain fungi.

Cornelius keg. A stainless steel cylinder which can be pressurized to a maximum of 130 PSI. When pressurized gas (usually CO₂) is forced into the gas port, it pushes the beverage from the bottom of the keg to a bottle or tap.

Cull. In a commercial orchard operation, fruit that does not meet fresh market standards due to poor color or size, skin blemishes, or other appearance flaws.

Enzymatic analysis. A method for determining the malic and lactic acid contents of apple cider using a spectrometer to measure the enzymes.

Espalier. A method of training and pruning trees to a narrow dimension along a trellis, wall, or other structure; in fruit trees, a way to increase light penetration and yield per unit area of orchard.

Fermentation. The biological process by which sugars are converted into cellular energy, producing ethanol and carbon dioxide. Yeasts carry out fermentation on sugars in the absence of oxygen (anaerobic). Fermentation is responsible for the production of ethanol in alcoholic beverages, among other common processes.

Fire blight. A bacterial disease that spreads from blossom to blossom by pollinating insects which carry the bacterium. Seldom found in cool maritime climates where bloom time is usually too cool for infection to occur.

Fourier transform infrared spectroscopy (FTIR). A nondestructive analytical laboratory technique based on the principle that molecular groups within a test sample will vibrate on exposure to infrared radiation, a method widely applied in the food industry.

Gibberellins. Plant hormones that regulate growth and influence various developmental processes; also called gibberellic acids.

Graft union. The point where a rootstock and scion are joined.

Growing degree days (GDD). Sum of the mean monthly temperatures above 50°F for the period concerned; expressed as degree days.

High pressure liquid chromatography (HPLC). A chromatographic technique for analysis that can separate a mixture of compounds; used in biochemistry and analytical chemistry to identify, quantify, and purify the individual components of a mixture. Also called high performance liquid chromatography.

Hydrometer. A device that measures the relative density or specific gravity of liquids; that is, the ratio of the density of the liquid to the density of water. Hydrometers are calibrated based upon the specific gravity of water at 60°F equal to 1.000.

Lees. The sediment and remains of yeast that accumulate in the bottom of a carboy, bottle, or other vessel after fermentation.

Lysozyme. An antimicrobial enzyme found in a wide variety of secretions such as egg white and tears.

Macroclimate. Regional climate, typically measured in square miles, depending on geographic factors.

Malolactic fermentation (MLF). The fermentation process converting malic acid to lactic acid and carbon dioxide. This fermentation is carried out by lactic acid bacteria which are present in apple juice and fermentation vessels, and can also be added as starter culture.

Meniscus. A curve in the surface of a substance (usually fluid) in contact with the surface of another object, such as a burette or measuring vessel. When reading a scale on the side of a container filled with liquid, the meniscus must be taken into account for a precise measurement.

Mesoclimate. Climate of a particular orchard plot, which may differ within a regional climate because of factors such as elevation, slope, or aspect.

Microclimate. Canopy climate, within and immediately surrounding a plant canopy, which can show differences between small areas within the canopy (i.e., sunlight exposure, humidity).

Paper chromatography. A method for analysis of complex chemical mixtures using progressive absorption of the unknown sample as a liquid on filter paper or other special paper.

Parts per million (PPM). A unit of concentration often used when measuring the amount of materials in air or water; 1 PPM is one part in 1,000,000. The common unit mg/l is equal to 1 PPM. Four drops of ink in a 55-gallon barrel of water would produce an ink concentration of 1 PPM.

Pasteurization. The process of heating a liquid at temperatures below its boiling point for the purpose of destroying undesirable microorganisms.

Patulin. A mycotoxin produced by certain fungal species of *Penicillium*, *Aspergillus*, and *Byssoschlamys* growing on fruit, especially decaying apples.

pH. A numerical measure of the acidity or hydrogen ion activity of a substance such as fruit juice or soil.

Pomace (pronounced PUM is). The solid remains of apples or other fruit after pressing for juice; contains the skins, pulp, seeds, and stems of the fruit.

Pommeau (pronounced pom OH). A drink, popular in Normandy, produced by blending unfermented apple juice and apple brandy in a barrel (the high alcoholic content of the spirit stops the fermentation process and the blend takes on the character of the aged barrel).

Pulp. The mixture of juice and fruit solids that results after fruit is milled and before pressing.

Rack. The process of transferring fermenting liquid such as cider or wine from one vessel to another to separate it from sediment (lees).

Refractometer. An instrument for measuring the Brix (soluble solids, which are an indicator of sweetness) of a liquid using the bending (refraction) of light. Handheld refractometers are commonly used for field testing.

Russet. Rough, leathery skin surface; may cover entire fruit or appear in veins or patches; usually brown or grayish. Also a descriptive name for certain apple varieties which have russet skin as a genetic characteristic, such as Roxbury Russet.

Sharp. Category of cider apple that is low in tannin (below 0.2%) and high in acid (above 0.45%), as defined by Williams (1975). Some dessert apples fall into this category.

Sorbitol. A sugar alcohol that occurs naturally in many fruits and berries; also called glucitol.

Specific gravity (SG). The relative density of a liquid compared to the density of water, standardized at 60°F to 1.000. Liquids that are more dense than water have a higher specific gravity, while liquids that are less dense than water have a lower specific gravity.

Stuck fermentation. When fermentation stops and the conversion of sugar to alcohol is incomplete.

Sulfites. A naturally-occurring sulfur compound sometimes used as a preservative and fumigant for its antimicrobial properties.

Sweating. Storing of harvested fruit for up to one month to ensure that as much starch as possible is converted into sugar.

Sweet. Category of cider apple that is low in both tannin (below 0.2%) and acid (below 0.45%), as defined by Williams (1975). Many dessert apples fall into this category.

Tannin. Astringent, bitter plant polyphenols found in all fruits, with higher concentrations in certain cider apples. Tannin produces a mouth-puckering taste like that of strong tea, and can be both bitter and/or astringent (hard or soft), depending on its chemical structure and other contributing factors.

Tensiometer. An instrument for measuring soil water content through surface tension.

Titrateable acidity (TA). The measure of organic acid content in juice (see Titration).

Titration. A common laboratory method of chemical analysis used to determine the unknown concentration of a known reactant such as acid content. Because volume measurements play a key role in titration, it is also known as volumetric analysis.

Varietal cider. A cider produced from a single apple variety, without mixing or blending of juice from other varieties.

Viscosity. A fluid's internal resistance to flow; a measure of fluid friction. For example, water is thin, having a low viscosity, while vegetable oil is thick, having a high viscosity.

Water core. A super-concentration of sugar in apple cells, usually near the core, making the fruit appear translucent. Affected apples are prone to rot and therefore have a reduced storage life.

Yeast available nitrogen (YAN). The nitrogen available in pressed juice that can support fermentation by yeasts, either wild or inoculated; measured in PPM.

REFERENCES & FURTHER READING

- Alcohol and Tobacco Tax and Trade Bureau. 2010. Wine. U.S. Department of the Treasury. <http://www.ttb.gov/wine/index.shtml>
- Blackburn-Maze, P. 1986. *The apple book*. Middlesex, England: Collingridge Books.
- Bureau of Alcohol, Tobacco and Firearms. 1998. Implementation of Public Law 105-34, Sections 908, 910 and 1415, related to hard cider, semi-generic wine designations, and wholesale liquor dealers' signs (97-2523). U.S. Department of the Treasury. *Federal Register* 63(162):44819-44820. <http://www.atf.gov/regulations-rulings/rulemakings/notices/notice-859.html>
- Chu, C.L.G. and K. Wilson. 2000. Evaluating maturity of McIntosh and Red Delicious apples. Ontario Ministry of Agriculture, Food, and Rural Affairs, Fact Sheet 00-025. <http://www.omafra.gov.on.ca/english/crops/facts/00-025.htm>
- Cider Advisory Committee. 1956. Revised list of recommended varieties of cider apples. In: Cider Advisory Committee Report. Long Ashton Research Station, Bristol, England.
- Colt, M., E. Fallahi, R. Hirnyck, and T. Lyon. 2001. Idaho crop profiles: Apples. University of Idaho CIS 1090. <http://www.cals.uidaho.edu/edComm/pdf/CIS/CIS1090.pdf>
- Cogger, C. 2005. Home gardener's guide to soils & fertilizers. Washington State University Extension Publication EB1971E. <http://cru.cahe.wsu.edu/CEPublications/eb1971e/eb1971e.pdf>
- Copas, L. 2001. *A Somerset Pomona: The cider apples of Somerset*. Dorset, England: The Dovecote Press.
- Food and Drug Administration. 2009. Hazard analysis and critical control points (HACCP). U.S. Department of Health and Human Services. <http://www.fda.gov/Food/FoodSafety/HazardAnalysisCriticalControlPointsHACCP/default.htm>
- Grove, G. and C-L. Xiao. 2005. Apple scab. Washington State University Extension Publication PNW0582. <http://cru.cahe.wsu.edu/CEPublications/pnw0582/pnw0582.pdf>
- Holz-Clause, M. 2003. Hard cider industry profile. Iowa State University, Agricultural Marketing Resource Center. http://www.agmrc.org/media/cms/hardciderprofile_FDF47F03DA2E8.pdf
- Idaho State Legislature. 2005. Alcoholic liquor defined. Title 23, Chapter 1, Section 23-105. <http://www.legislature.idaho.gov/idstat/Title23/T23CH1SECT23-105.htm>
- Iland, P., A. Ewart, and J. Sitters. 1993. Techniques for chemical analysis and stability tests of grape juice and wine. Patrick Iland Wine Promotions, Campbelltown, South Australia.
- Lea, A. 1999. Cider flavour descriptors. Wittenham Hill Cider Portal. <http://www.cider.org.uk/flavour.htm>
- Lea, A. 2008. *Craft cider making*. Preston, England: The Good Life Press.
- Mattheis, J. 1998. Maximizing postharvest quality of Gala and Fuji apples. 14th Annual Postharvest Conference, Yakima, WA, March 10-11. <http://postharvest.tfrec.wsu.edu/pgDisplay.php?article=PC98N>
- Merwin, I, S. Valois, and O. Padilla-Zakour. 2008. Cider apples and cider-making techniques in Europe and North America. *HortReviews* 34:365-415.
- Mitchell, P. 2006. *Cider and perry: Sensory evaluation*. Course manual. Pershore, UK: Mitchell F&D Limited.
- Mitchell, P. 2007. *Cider and perry: Adding value*. Course manual. Pershore, UK: Mitchell F&D Limited.
- Mitchell, P. 2009. *Cider making: Principles and practice*. Course manual. Pershore, UK: Mitchell F&D Limited.
- Mitchell, P. 2010. Training programmes for the cider industry. Mitchell F&D Limited. <http://www.cider-academy.co.uk>
- Mohr, W.P. 1988. Apple cultivars for juice and cider production. Agriculture Canada Technical Bulletin 1988-6E, Smithfield Technical Bulletin No. 7. Trenton, Ontario.
- Morgan, J. and A. Richards. 1993. *The book of apples*. London, England: Ebury Press..

- Moulton, G.A. 1995. Growing Jonagold in western Washington. Washington State University Extension Publication EB1804. <http://cru.cahe.wsu.edu/CEPublications/eb1804/eb1804.html>
- Moulton, G.A. 1996. Easy steps to fruit tree pruning. 60-minute DVD. Conway, WA: Cedardale Orchards. <http://pruning.com/default.htm>
- Moulton, G.A., G.H. Spitler, J. King, L.J. Price, and D. Zimmerman. 2004. Annual report 2004: Evaluation of apple cultivars for hard cider production. Washington State University Mount Vernon Northwestern Washington Research and Extension Center. <http://maritimefruit.wsu.edu/Cider04.html>
- Mount Vernon Northwestern Washington Research and Extension Center (NWREC). 2010. Tree Fruit and Alternative Fruits for Western Washington: Hard Cider. Washington State University. <http://maritimefruit.wsu.edu/Cider.html>
- Oregon State Legislature. 1997. Tax on cider. ORS 473.035 http://www.lawserver.com/law/state/oregon/or-statutes/oregon_statutes_473-035
- Oregon State University. 2010 Pest management guide for tree fruits in the mid-Columbia area. EM8203E. <http://ir.library.oregonstate.edu/jspui/bitstream/1957/14105/1/EM8203.pdf>
- Oregon State University Extension. 2010a. Apple (*Malus*)—Anthracnose (bull's eye rot). In: *An online guide to plant disease control*. <http://ipmnet.org/plant-disease/disease.cfm?RecordID=36>
- Oregon State University Extension. 2010b. Apple — Scab. In: *An online guide to plant disease control*. <http://plant-disease.ipmc.orst.edu/disease.cfm?RecordID=55>
- Orton, V. 1995. *The American cider book: The story of America's national beverage*. New York: North Point Press.
- Parker, R. and C.A. Ramsay. 2008. Agricultural weed management principles. Washington State University Extension Publication MISC0167.
- Peters, R. T., H. Neibling, and M. English. 2010. Irrigation in the Pacific Northwest. <http://irrigation.wsu.edu/>
- Proulx, A. and L. Nichols. 1997. *Cider: Making, using and enjoying sweet and hard cider*. 2nd edition. Pownal, VT: Storey Publishing.
- Righetti, T., K. Wilder, R. Stebbins. D. Burkhardt, and J. Hart. 1998. Nutrient management guide: apples. Oregon State University Extension EM8712. <http://extension.oregonstate.edu/catalog/pdf/em/em8712-e.pdf>
- Rowles, K. 2000. Processed apple product marketing analysis: Hard cider and apple wine. Cornell University, SP 2000-06. <http://hortmgt.aem.cornell.edu/pdf/resources/sp2000-06.pdf>
- Stebbins, R.L. 2003. Training and pruning your home orchard. Pacific Northwest Extension Publication PNW400. <http://extension.oregonstate.edu/catalog/pdf/pnw/pnw400.pdf>
- Stiles, W.C. and W.S. Reid. 1991. Orchard nutrition management. Cornell University Cooperative Extension. Information Bulletin 219. <http://ecommons.cornell.edu/bitstream/1813/3305/2/Orchard%20Nutrition%20Management.pdf>
- Symon, K. 1971. *Mechanics*. 3rd edition. Menlo Park, CA: Addison-Wesley.
- University of Idaho Extension. 2010. Pest Management Center. <http://www.uhome.uidaho.edu/ipm>
- Washington State Legislature. 2009. Imposition of taxes on sales of wine and cider—Additional taxes—Distributions. Revised Code of Washington. RCW 66.24.210. <http://apps.leg.wa.gov/rcw/default.aspx?cite=66.24.210>
- Washington State Pest Management Resource Service. 2009. Analytical laboratories and consultants serving agriculture in the Pacific Northwest. Washington State University. <http://www.puyallup.wsu.edu/analyticallabs/>
- Washington State University Extension. 2010 Crop protection guide for tree fruits in Washington. Washington State University Extension Publication EB0419. <http://cru.cahe.wsu.edu/CEPublications/eb0419/EB0419.pdf>
- Watson, B. 1999. *Cider, hard and sweet: History, traditions, and making your own*. Woodstock, VT: The Countryman Press.
- Williams, R.R. 1975. An introduction to modern cider apple production. Long Ashton Research Station, Bristol, England.
- Zoecklein, B.W., K.C. Fugelsang, B.H. Gump, and F.S. Nury. 1995. *Wine analysis and production*. New York: Chapman & Hall.

Pacific Northwest Extension publications are produced cooperatively by the three Pacific Northwest land-grant universities: Washington State University, Oregon State University, and the University of Idaho. Similar crops, climate, and topography create a natural geographic unit that crosses state lines. Since 1949, the PNW program has published more than 600 titles, preventing duplication of effort, broadening the availability of faculty specialists, and substantially reducing costs for the participating states.

Pacific Northwest Extension publications contain material written and produced for public distribution. You may reprint written material, provided you do not use it to endorse a commercial product. Please reference by title and credit Pacific Northwest Extension publications.

Copyright 2010 Washington State University.

Order information:

Washington State University Extension
<http://pubs.wsu.edu>
Fax 509-335-3006
Toll-free phone 800-723-1763
ext.pubs@wsu.edu

Oregon State University Extension Service
<http://extension.oregonstate.edu/catalog>
Fax 541-737-0817
Toll-free phone 800-561-6719
puborders@oregonstate.edu

University of Idaho Extension
<http://www.cals.uidaho.edu/edComm/catalog.asp>
Fax 208-885-4648
Phone 208-885-7982
calspubs@uidaho.edu

Published and distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914, by Washington State University Extension, Oregon State University Extension Service, University of Idaho Cooperative Extension System, and the U.S. Department of Agriculture cooperating. WSU Extension programs, activities, materials, and policies comply with federal and state laws and regulations on nondiscrimination regarding race, sex, religion, age, color, creed, and national or ethnic origin; physical, mental, or sensory disability; marital status or sexual orientation; and status as a Vietnam-era or disabled veteran. Washington State University Extension, The Oregon State University Extension Service, and University of Idaho Extension are Equal Opportunity Employers. Evidence of noncompliance may be reported through your local Extension office. Trade names have been used to simplify information; no endorsement is intended. Published November 2010.