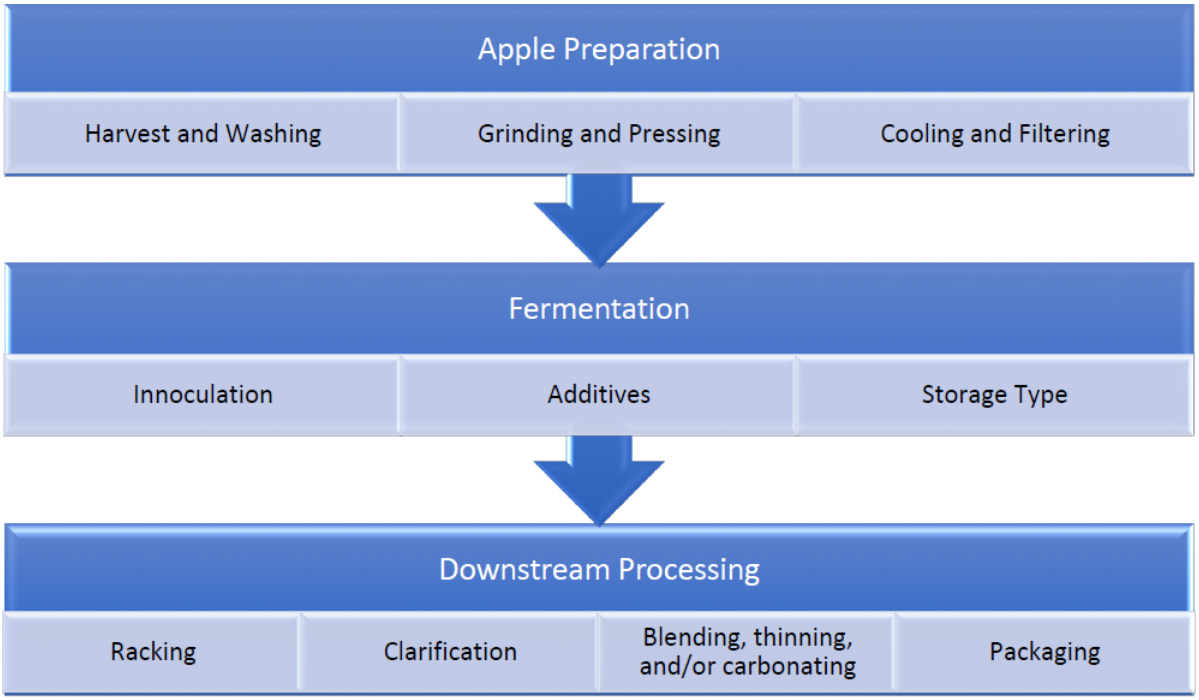
1.14: Cider

Cider Production

Cider is a drink made from apples. In the US, cider can refer to apple juice or the fermented, alcoholic version. This section will focus on the fermented, alcoholic drink.

Typical Steps in Cider Production:



Step 1: Apple Preparation

Choosing Apple Varietals

Apples are the primary material used in cider production; thus, the final cider product quality and style depend heavily upon the quality of the apples used. Apples must be juicy, sweet, and ripened. A full-bodied cider requires the use of several different types of apples to give it a balanced flavor including a mix of sweet and tart apples.

? Exercise 1.14.1

There are four main apple varietals. List them and their flavors.

Milling and Pressing

Apples are not peeled as the skin of the apples contains many of the compounds that contribute to the taste of the cider. The apples are ground and then pressed to extract the juice. The primary components of an apple are shown in Table 14.1. The fiber and insoluble carbohydrates are mostly removed in the pressing process.

Table 1.14.1 Raw Apple Components

Constituent	Approximate Composition
Water	80%
Carbohydrates (mono-, disaccharides)	5%
Carbohydrates (cellulose, mostly removed in pressing)	5%
Malic Acid	4-6%

Constituent	Approximate Composition
Pectin	1%
Polyphenols, tannins	--
Vitamins, Minerals	4%
Proteins	--

After pressing, the juice can be pasteurized and sold as apple juice or it can be further processed with fermentation to produce the alcoholic beverage.

Components of Cider Apple Juice: Sugars

The primary sugars found in cider apple juice before fermentation are fructose, glucose, and sucrose.

? Exercise 1.14.2

- Draw these three structures of fructose, glucose, and sucrose.
- Would most bacteria or yeast be able to ferment these saccharide structures? Or would these sugars need to be hydrolyzed first?

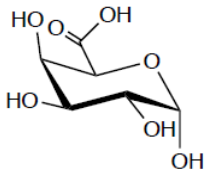
On a commercial scale, there are considerable cost advantages to supplementing the raw apple juice with glucose syrup and water as they are cheaper than apple juice. In fact, many commercial ciders are now made from around 35% juice and 65% glucose syrup.

? Exercise 1.14.3

How would this impact the flavor?

Components of Cider Apple Juice: Pectins

Pectin is a polysaccharide made from a mixture of monosaccharides. While many distinct polysaccharides have been identified and characterized within these 'pectic polysaccharide family', most contain stretches of linear chains of α-(1–4)-linked D-galacturonic acid.



galacturonic acid

? Exercise 1.14.4

Draw a linear chain of linear chains of α-(1–4)-linked D-galacturonic acid.

Most wild type yeasts cannot ferment galacturonic acid but failure to remove the pectin can lead to the formation of jelly during concentration. Thus, pectolytic enzymes are sometimes added prior to fermentation. This pectinase treatment often results in a release of higher concentrations of anthocyanins, tannins, and polyphenols from the apple pressings.

? Exercise 1.14.5

How could the increased level of tannins and phenols impact the flavor of the final cider?

Remaining pectin polysaccharides cause a haze in finished ciders, so pectinase is also sometimes added after fermentation to clear the cider.

Exercise 1.14.6

How would the presence of alcohol in the finished cider impact the effectiveness of the pectinase?

French cider is often prepared with an initial step, '*defecation*', in which pectins and other substances are separated from the juice using a gelatin. T hen, the clear juice is fermented slowly.

Exercise 1.14.7

These ciders are fruitier than others. Explain.

Sulfuring

Many cider makers add sulphur dioxide (or potassium metabisulphite) to inhibit the growth of most spoilage yeasts and bacteria, while permitting the desirable fermenting yeasts (such as *Saccharomyces cerevisiae* or *uvarum*) to facilitate the conversion to alcohol.

Exercise 1.14.8

- Draw the Lewis structure of sulfur dioxide, SO_2.
- Sulfur dioxide in water is rapidly converted to H_2SO_4. Show a mechanism.

Most natural weak acid preservatives (such as vinegar, benzoic acid or sorbic acid) are believed to work by diffusing through bacterial cell membranes. The increased acidity of the cytoplasm disrupts the cell homoeostasis and the cell has to work very hard to pump out protons to restore the pH. Eventually, the cells run out of ATP and die. Sulphite is believed to work in the same way as other weak acid preservatives.

Step 2: Fermentation

Fermentation Yeasts

Apple juice (must) was traditionally fermented with the bacteria and yeast already present on the apples.

The main yeasts found in wild fermentations is *Saccharomyces bayanus*. But *Saccharomyces cerevisiae*, *Lachancea cidri*, *Dekkera anomala* and *Hanseniaspora valbyensis* are also present is substantial amounts. Other species are present in small amounts: *Candida oleophila*, *C. sake*, *C. stellate*, *C. tropicalis*, *H. uvarum*, *Kluyveromyces marxianus*, *Metschnikowia pulcherrima*, *Pichia delftensis*, *P. misumaiensis* and *P. nakasei*.

There are three phases in the cider process based on the dominant yeast species present.

1. The first phase, which they called 'the fruit yeast' phase, is dominated by *Hanseniaspora uvarum/Kloeckera apiculata* yeasts.
2. The second phase, or 'fermentation phase' where the alcoholic fermentation occurs with the replacement of non-Saccharomyces yeasts by the strong fermenting *Saccharomyces* yeasts, such as *S. bayanus* and *S. cerevisiae*.
3. The last 'maturation phase' is dominated by *Brettanomyces/Dekkera* yeasts.

Exercise 1.14.9

- Many large industrial cider factories use heavy sulfiting to _____ and then add purified *Saccharomyces* wine yeasts.
- Suggest a reason that industrial cider factories choose not to use wild fermentation.
- Craft cider-makers will often still use wild fermentation. Suggest a reason that they choose to use wild fermentation.
- During alcoholic fermentation, sugars are converted mainly into _____ and _____ by yeasts (mainly *Saccharomyces* sp.). The varietal choice and maturity of the fruits influence the sugar content of the starting must and, thus, the final ethanol level.

Fermentation should take 5 to 10 days, and up to 4 - 6 weeks at cool temperatures. Nearly all the sugar will then have been used by the yeast and the yeast will become dormant.

? Exercise 1.14.9

Propose how cider-makers would determine when to stop fermentation.

During alcoholic fermentation, many secondary metabolites are produced by the yeasts. Esters provide mainly fruity and floral notes; higher alcohols provide 'background flavors'; whereas the phenolic compounds can generate interesting or unpleasant aromatic notes.

Esters are the main volatile compounds in cider. They are characterized by a high presence of ethyl acetate, which alone can represent up to 90% of the total esters.

? Exercise 1.14.10

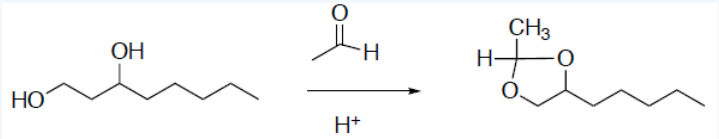
- What are the fusel alcohols and how are they formed?
- Draw ethyl acetate and review the metabolic process for its synthesis from fermenting yeasts.

Dioxanes, key flavor components of cider, are described as a 'green, cidery' flavor that results only from alcoholic fermentation of apples (and pears).

These dioxanes are formed from reaction of acetaldehyde or other aldehydes (fermentation byproduct) with diols which are found almost exclusively in apples.

? Exercise 1.14.11

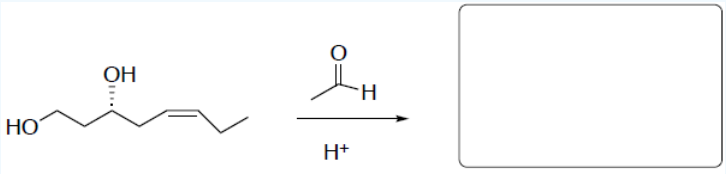
Propose a mechanism for this reaction of acetaldehyde and octane-1, 3-diol.



Another dioxane found in cider is formed from acetaldehyde and (R)-5(Z)-octene-1,3-diol.

? Exercise 1.14.12

Draw the product found in cider.



Step 3: Post-fermentation Processing

Racking and Fining

Racking is the process of moving the cider from its ***lees*** (the sediment formed).

This is usually a filtration or centrifugation process.

Pectinase may be added at this point.

? Exercise 1.14.13

What is the purpose of this step?

After racking, the cider maker may choose to do a secondary fermentation. Yeast might be added to ensure a sparkling cider, or a malolactic acid fermentation will be used to improve the flavor. (See next sections).

Aging

Cider was traditionally stored in wooden barrels to age, but this is not essential if chilling and fining have been properly carried out after the fermentation.

The bacteria needed for malolactic acid are often founded in the wood barrels.

Secondary Fermentation: Malolactic Fermentation

Cider fermentation with LAB bacteria convert the sugars and the malic acids into lactate. Malolactic fermentation is primarily completed by *Leuconostoc oenos*, a heterofermentative organism. This process tends to create a rounder mouthfeel to the final cider. Malic acid is typically associated with the taste of green apples, while lactic acid has a richer taste.

Table 1.14.2

Nutrient	Homofermentive LAB	Heterofermentive LAB
Glucose	Lactate	Lactate, ethanol, CO_2
Fructose	Lactate	Lactate, ethanol, CO_2
Malate	Lactate, CO_2	Lactate, ethanol, CO_2
Citrate or Pyruvate	Acetoin, Diacetyl, CO_2	Lactate, acetate, CO_2

? Exercise 1.14.14

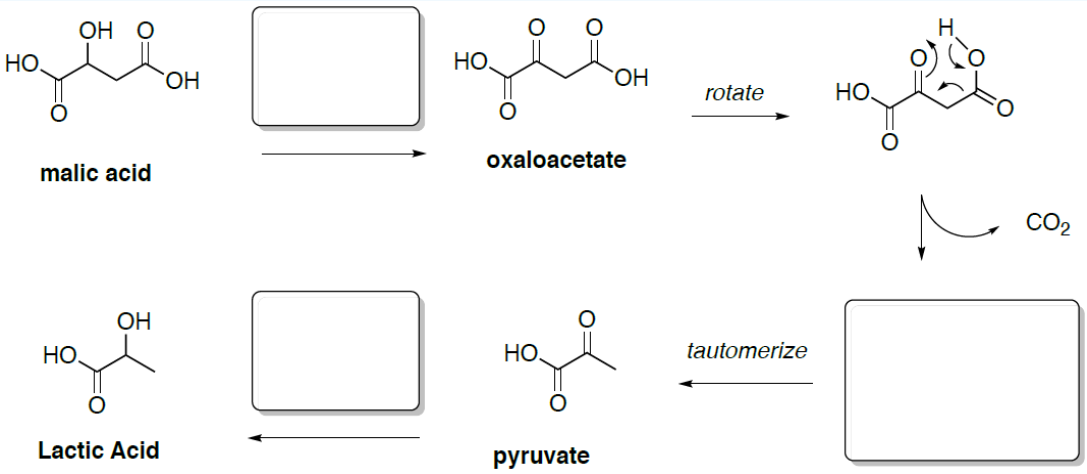
- *Review*: What is the difference between homofermentive and heterofermentive?
- Malolactic fermentation is favored by [**high / low**] sulphiting during fermentation.

Secondary Fermentation: Malolactic Fermentation Pathway

The malolactic fermentation involves the conversion of malic acid into lactic acid and carbon dioxide. Some LAB bacteria convert the malic acid in one step; while others utilize these steps that include intermediates from the TCA cycle.

? Exercise 1.14.15

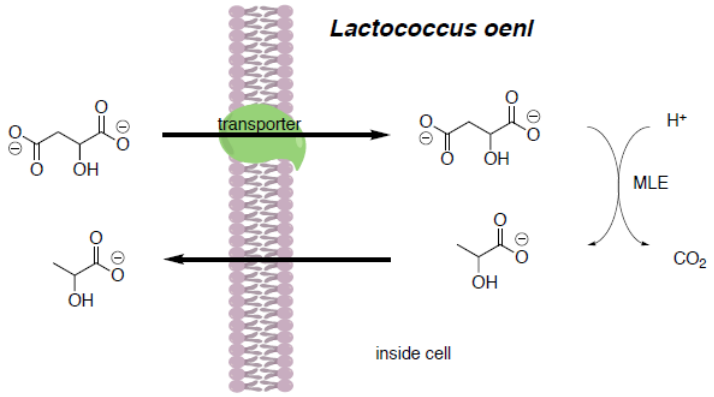
Complete the steps in this biochemical pathway to convert malic acid to lactic acid.



- What is the net NAD^+ / NADH change?
- For many bacteria, the goal of fermentation is to regenerate the [**NAD^+ / NADH**] utilized in the glycolysis pathway as they do not have the enzymes for oxidative phosphorylation where this occurs in eukaryotes.

If malolactic fermentation is not fulfilling this function, then there must be some energy gain for the organism in completing this process.

Secondary Fermentation: Malolactic Fermentation Energy and pH



MLF process is shown. This reaction allows cells to regulate their internal pH.

? Exercise 1.14.16

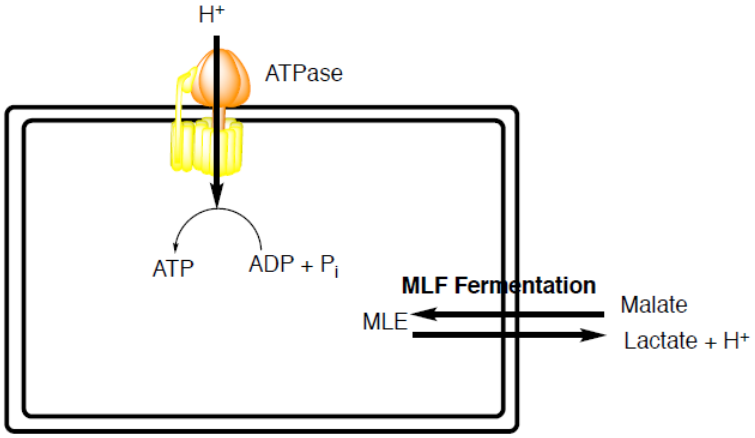
What happens to the overall H^+ concentration inside the cell?

This reaction allows cells to gain energy by creating a proton gradient across cell membranes. Some bacteria can utilize citrate or malate. The process allows out 1-2 proton atoms to be pumped out of the cell into the periplasm.

? Exercise 1.14.17

Suggest a method for pumping out 2 H^+ instead of 1 H^+ in this process.

The proton gradient created from MLF is coupled to an ATPase which captures the energy in the production of new ATP molecules.



In cider production, this is important to reduce the malic acid content AND the overall raw acidic flavor of the cider.

? Exercise 1.14.18

The proton pump will **[increase / decrease]** the acidity of the cider product (outside the cell).

Depending upon the organism, these processes are inhibited with higher alcohol content and below pH of 3-4.

? Exercise 1.14.19

If a cider producer wants to inhibit MLF in the cider, the pH of the must can be [**lowered / raised**] to prevent the process.

Sweet Still Cider

Ciders are naturally 'dry'. The term 'dry' means that there is little sweetness from remaining sugars, but more flavor from alcohol, fusel alcohols, esters, etc. Some consumers prefer a sweet still cider.

? Exercise 1.14.20

Propose at least two methods for ensuring a sweet cider.

Sparkling Ciders: Gasification and Bottling

To get some bubbles into cider, excess carbon dioxide under pressure can be added and then the cider is bottled or put in a keg which will withstand the pressure.

Sparkling Ciders: Secondary Fermentation for Gasification

Commercial cider-makers will sometimes inoculate with active dry yeast (*Saccharomyces cerevisiae*) before bottling to obtain a naturally-carbonated beverage.

? Exercise 1.14.21

Because there is not much sugar left in the cider at this point, _____ is often added when using a second fermentation.

This can be very successful although the bottom of each bottle will inevitably be a little cloudy when poured, because there will always be some yeast deposit which will be roused up when the pressure is released.

Note: Bottles used for carbonated ciders must be designed to withstand the pressure generated by the gas!

Stabilization

After all fermentation processes are complete, the must is either pasteurized or treated with ascorbic acid or sulfur dioxide.

? Exercise 1.14.22

- What is the purpose of this step?

This step also decreases the chance of contamination by Acetobacter.

- What happens if Acetobacter is present?

Sources

1. Kavvadias, et. al. J. Agric. *Food Chem.* **1999**, *47* (12), 5178-5183.
2. Cox and Henick-Kling, Chemiosmotic Energy from Malolactic Fermentation, J. Bacteriol. 1989, 5750-5752.