Alcohols, Acids, and Esters in Beer

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What are Alcohols, Acids, and Esters?

- **Alcohols**
  - Any organic molecule with a hydroxyl group (X~OH) that’s attached to a saturated (fully occupied) carbon atom

- **Acids**
  - Any molecule that can lower the pH of a solution by releasing a hydrogen ion (H⁺)
  - Most organic acids found in beer are carboxylic acids (X~OOH → X~OO⁻ + H⁺)

- **Esters (organic)**
  - Any organic compound that has an oxygen atom bound in between two carbon atoms (X~C-O-C~Y)
  - In beer, esters are usually derived from an alcohol molecule and a carboxylic acid molecule
    - A~OH + B~OO⁻ → A~O~B + H₂O
Main Alcohols Found in Beer

- **Ethanol**
  - Main product of yeast fermentation

- **Fusel Alcohols**
  - Long chain alcohol molecules (ethanol plus extra carbon atoms)
  - Often referred to as tasting “hot” or “spicy/burning”
  - Usually formed due to poor yeast health and/or hot fermentation temperatures

- **Geraniol**
  - Found in hops
  - Has a rose-like scent in its pure form

- **Terpineol**
  - Alcohol derived from yeast metabolism of hop compounds
  - Has a lilac-like scent in its pure form
Main Acids Found in Beer

- **Acetic acid**
  - Sour, vinegar-like taste
  - In beer, usually produced by either Acetobacter or Brettanomyces
  - Requires oxygen to be formed in beer

- **Lactic acid**
  - Sour milk/yogurt flavor
  - Produced in beer by Lactic Acid Bacteria (LAB)
    - Common LAB in beer are Lactobacillus or Pediococcus

- **Butyric acid**
  - Stinky feet and/or baby diaper smell/taste
  - Produced by Enteric bacteria (e.g. E. coli) during early stages of beer/wort production

- **Ferulic acid**
  - Precursor to the “clove-like” phenol (4-vinyl-guaiacol) found in German Hefeweizens
  - Derived from barley or wheat

- **Many, many more**
Alcohols and Acids Combine to Form Esters in Beer

<table>
<thead>
<tr>
<th>Alcohol</th>
<th>Acid</th>
<th>Ester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethanol</td>
<td>Acetic</td>
<td>Ethyl Acetate (Pear at low levels; nail polish remover at high levels)</td>
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<tr>
<td></td>
<td>Lactic</td>
<td>Ethyl Lactate (Sweet Cream)</td>
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<tr>
<td></td>
<td>Butyric</td>
<td>Ethyl Butyrate (Pineapple)</td>
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<tr>
<td></td>
<td>Ferulic</td>
<td>Ethyl Ferulate (Cinnamon; Woody)</td>
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<tr>
<td>Geraniol</td>
<td>Acetic</td>
<td>Geranyl Acetate (Geranium)</td>
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<tr>
<td></td>
<td>Butyric</td>
<td>Geranyl Butyrate (Geranium)</td>
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<tr>
<td>Terpineol</td>
<td>Acetic</td>
<td>Terpinyl Acetate (Cherry)</td>
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<tr>
<td></td>
<td>Butyric</td>
<td>Terpinyl Butyrate (Cherry)</td>
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</tbody>
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Other Interesting Ester Flavors/Sources

- **Tobacco/Fig or Smoky/Burnt/Vanilla**
  - From acids in oak that combine with ethanol
- **Raspberry or Kiwi/Pineapple/Strawberry**
  - From certain acids made by bacteria that combine with ethanol
- **Unripe Banana, Pineapple, or Apple**
  - Certain compounds produced during Saccharomyces and/or Brettanomyces fermentations that combine with ethanol
- **Many, many other flavors**
  - Certain fusel alcohols can be combined with acetic/lactic acid by Brettanomyces to form compounds with multiple, complex flavors
Factors Influencing Ester Formation in Beer

- Temperature
  - High fermentation temperatures favor the formation of esters and ester precursors

- Oxygenation
  - Low oxygenation rates tend to drive ester production

- Yeast pitching rate
  - Low pitching rates favor high yeast growth rates and high ester production
  - High pitching rates cause low yeast growth rates and reduced ester production

- Wort production
  - Wort that becomes contaminated with Enteric bacteria can have butyric acid present which can be later turned into ethyl butyrate
    - This can be found in spontaneous beer production or during kettle-souring using poor technique
  - Mashing using a ferulic acid rest (113°F) can yield more of this compound for future esterification
Avoiding Off-Flavors from Alcohols, Acids, and Esters

- **Alcohols**
  - Fusels - Keep the fermentation temperature at the proper level for that yeast, properly oxygenate the wort, and pitch enough healthy yeast for the OG of the beer

- **Acids**
  - Acetic/lactic/butyric - Keep unwanted organisms out of your beer (i.e. good sanitation and avoid cross-contamination between sour and clean beer equipment or other fermenting goods)
  - Acetic - During Brett fermentations, limit oxygen ingress as much as possible

- **Esters**
  - Use a low ester-producing yeast (e.g. not English or Belgian yeast strains) and pitch a large amount of healthy yeast
  - Ferment at the lower end of the temperature range for that particular yeast
  - Oxygenate your wort prior to pitching yeast
Ester Production in Sour Beers

- In sour beer fermentations, mixed-cultures (e.g. Saccharomyces and Brettanomyces in the same beer) can produce esters that aren’t made by either organism on their own
  - This is why Sacc-only or Brett-only beers can be quite clean, but mixed-culture beers can be fruity/funky
- Many sour beers benefit from small amounts of oxygen exposure during fermentation
  - A small amount of oxygen can be used to make low levels of acetic acid, which can be combined with various alcohols (ethanol or fusels) to form esters
  - Too much oxygen exposure will make an unpleasantly large amount of acetic acid
    - This can combine with ethanol to make large amounts of ethyl acetate (nail polish remover), especially if the fermentation reaches high temperatures (80°F+)
One Last Note

- One main thing to keep in mind is that many compounds, including esters and ester precursors, change in concentration over time.
- If a beer contains certain off-flavors, those compounds can be converted to esters over time, which usually taste much better.
  - Just be sure to store the “bad” beer at cellar or room temperature for this maturation process.
- Esters are transient compounds.
  - If an estery beer tastes good, drink it then/store it cold as these compounds can fade.
  - If a beer is too estery, let it age until the levels of these flavors subside.
Additional Information

- Sour Beer Blog - Article on Esterification