Aromachemicals Found in The Brewing Process & Finished Beer – Part 1

26th April 2025

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i. Overview
ii. The mash
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(i) Overview

Aromachemicals

- Organic Chemicals that are used for their smell and/or taste characteristics
- Natural
- Synthetic

(i) Overview

- The Mash
- Fermentation – Lag Phase
- Fermentation – Growth Phase
- Fermentation – Stationary Phase
- Conditioning & Aging

(ii) The Mash: Effects of Sugars

The type of sugars present can affect fermentation flavours.

As a general rule, simpler sugars are more fermentable than longer chain, more complex sugars.

Yeast utilise some sugars more easily than others, they take up sugar in a specific order, with simpler sugars first: glucose, fructose, sucrose, maltose, and then maltotriose.

Most of the sugar in a typical all-malt wort is maltose, with lesser amounts of glucose and maltotriose.

Yeast take glucose into the cell through facilitated diffusion, without expending any metabolic energy. It is so easy for yeast to utilize glucose that the presence of glucose actually suppresses the yeast’s ability to utilize maltose and maltotriose.

The type of sugars present can also affect fermentation flavours.

Fermentation of wort high in glucose, from added adjuncts, produces beers with higher than normal concentrations of esters (particularly **ethyl acetate,** which tastes like adhesive or solvent, and **isoamyl acetate**, which tastes like banana). 3,4

Conversely, wort high in maltose results in lower concentrations of these esters. The higher the starting gravity, the more pronounced this effect.

(ii) The Mash: Effects of Sugars

Difference sources of malt can contribute to Sulphur compounds such as **dimethyl sulphoxide (DMSO)**, depending on the source malt.

More on this later

(iii) Yeast & Fermentation

Yeast transforms sugars to ethanol + water

This is a complex enzymatic process.

While metabolizing the extract, yeast cells also produce hundreds of other compounds.

These compounds exist in very small amounts, the sum total of which is less than 1 percent of the mass of the metabolised extract, but they contribute enormously to flavour and contribute what is the essence of beer.

The types and amounts of these flavour compounds are by no means constant and can vary enormously depending on yeast health, growth rate, sanitation, and other factors.

(iii) Yeast & Fermentation

Although Yeast cells produce most of their fermentation flavour compounds in the first 72 hours, yeast produce minimal flavour compounds during the lag phase as the yeast produce minimal ethanol at this stage, so ester formation cannot happen.

Yeast do not create esters until they first make an appreciable amount of alcohols during the growth phase.

When yeast ferments the wort, a transformation occurs from a sugary solution to an alcoholic one, and the pH drops to around 4.0-4.5.

A lower pH gives fermented products added protection against harmful bacteria and is conducive to the production the flavour compounds that add the characteristics that make beer taste the way it does.

(iii) Yeast & Fermentation

Yeast contribute much of the aroma, flavour and character of beer:

- By products react with ethanol and themselves;
- carbon dioxide is produced which affects the tasting experience;
- fermentation also affects mouthfeel

Even with the same ingredients, with different fermentations yield different results. This happens because so many enzymatic pathways are involved in yeast fermentation.

Environmental factors not only affect which genes are active, but also how actively the yeast cells grow, the health of the cells, what sugars they consume, and many other things."

The growth rate affects the quantity and makeup of flavour compounds.
More cell growth usually results in more flavour compounds.

(iii) Yeast & Fermentation

Oxygenation

It is possible to over oxygenate your wort when using pure Oxygen. If you provide an overabundance of oxygen, too much growth can occur, creating an overabundance of fermentation by-products and resulting in a less than ideal fermentation character.

Even though most yeast strains are able to cope with high levels of dissolved oxygen, it is possible to provide so much that it becomes a beer flavour problem.

Excessive usage of pure oxygen results in high levels of Fusel Alcohols, increased Acetaldehyde, and other flavour problems.

Higher concentrations of **Acetaldehyde** are due to oxidation of Ethanol. xx

This should be considered at every stage of the process post fermentation and also the effects of oxidation of the hop aromas & flavours.

(iii) Yeast & Fermentation

Yeast can produce five hundred different flavour and aroma compounds

After pitching, yeast undergo a lag phase, which is then followed by a very rapid exponential growth phase.

During both the lag and exponential phase, yeast build amino acids, proteins, and other cell components.

Most of these components do not affect the flavour of the beer, but the pathways involved in their production also create many other compounds that leak out of the cell and impact beer flavour.

The compounds with the largest flavour impact are **fusel alcohols, organic acids, esters, sulphur-containing compounds, and carbonyl compounds like aldehydes and ketones (including diacetyl)**.

Although many of these compounds play a role in the characteristic flavour and aroma of beer, it is a beer flaw when some of these compounds reach higher, easily detectable levels.

(iii) Yeast & Fermentation

Warmer fermentation shows a small increase in production of ethanol, fusel alcohols, and esters, but the main flavour difference is a substantial increase in **Acetaldehyde.** xx

Once it reaches fermentation temperature, hold the temperature steady until at least the last one-third to one-fourth of fermentation.

At this point, yeast growth slows down, and the yeast enter into a stationary phase.

The yeast have already produced most of the flavour and aroma compounds, which include Fusel Alcohols, Esters, and Sulphur compounds so there is little risk of increased flavours.

This “green beer,” or “young beer” has not yet reached a proper balance of flavours

(iii) Yeast & Fermentation

Beer matures in the stationary phase, also known as the conditioning phase.

Yeast reabsorb much of the **diacetyl** and **acetaldehyde** produced during fermentation, and **hydrogen sulphide** continues to escape from the top of the fermenter as a gas.

So at this time raise the temperature several degrees or more (2 to 5°C) over the course of a day or two.

The benefit is that the higher temperature near the end of fermentation aids yeast activity. The yeast are more likely to attenuate fully and reduce intermediary compounds produced earlier in fermentation. The rise in activity will also aid in driving off some volatile compounds, such as **sulphur compounds**."

(iii) Yeast & Fermentation

Sulphur Compounds

The sulphur compounds typically found in beer are **Dimethyl Sulphide (DMS),** Sulphur Dioxide (SO_2), Hydrogen 5
Sulphide (H_2S), and Mercaptans.

Some of these sulphur compounds come from malt, while others come from yeast or a combination of both.

For example, Dimethyl Sulphoxide (DMSO) - oxidized DMS - is present in wort at varying levels, depending on the source malt. The level of DMSO is not affected by the boil like DMS. Unfortunately, yeast has the ability to reduce DMSO back to DMS during fermentation, increasing the level of those canned corn and cooked cabbage types of aromas and flavours in the beer.

Yeast produce SO_2, which not only flavours the beer but gives it antioxidant properties. People often describe the aroma of SO_2 as similar to a burnt match.

SO_2 easily reduces to another sulphur compound, H_2S, which is the compound with a rotten egg smell. Fortunately, the CO_2 released from fermentation carries most of the H_2S out of the beer.

The key to reducing these sulphur compounds in beer is to have an active, healthy fermentation.

(iii) Yeast & Fermentation

Sulphur Compounds

The lower temperature of lager brewing is a key factor in higher sulphur levels.

The lower temperatures of lager fermentation generally result in a less vigorous fermentation (less physical movement of the wort) and less evolution of gases due to higher gas solubility at those temperatures.

Lager yeast work more slowly and produce fewer esters and fusel alcohols at cooler fermentation temperatures, usually 10 to 13°C, but the slower fermentation and cool temperatures not only keep more sulphur in solution but make it harder for the yeast to reabsorb diacetyl.

(iii) Yeast & Fermentation

Diacetyl

Diacetyl, even at low levels, can contribute slickness or slipperiness to a beer's mouthfeel. In higher quantities, diacetyl gives beer a buttery or butterscotch like aroma and flavour. Diacetyl is a small organic compound that belongs to the ketone chemical group. Another ketone commonly found in beer is **2,3-pentanedione, (Acetyl Propionyl).** 6,7

Yeast has the ability to reduce diacetyl enzymatically.

During growth yeast produces acetolactate, the precursor for diacetyl.

Later, during the stationary phase, yeast reabsorbs diacetyl and converts it to acetoin and subsequently to 2,3-butanediol. Both acetoin (**Acetyl Methyl Carbinol, AMC**) and 2,3-butanediol (Butylene Glycol) can escape the cell, but AMC may contribute to the flavour profile. 8

(iii) Yeast & Fermentation

Diacetyl

Yeast health and yeast activity play a major role in diacetyl levels. Since temperature plays a major role in yeast activity, temperature affects Diacetyl levels.

As fermentation temperature increases so does Diacetyl production and reduction. Higher temperature results in faster yeast growth and more Acetolactate. The higher the Acetolactate, the higher the Diacetyl.

However, a higher temperature also increases Diacetyl digestion & reduction during the Conditioning Phase.

A warm-fermented ale may have a higher Diacetyl peak than a cold-fermented lager, but the reduction of Diacetyl happens much faster at Ale temperatures.

(iii) Yeast & Fermentation

Diacetyl

Most yeast strains, when healthy and active, will rapidly reduce diacetyl below flavour threshold given enough time and temperature.

While lower yeast growth rates can reduce the amount of Acetolactate produced, it can result in higher levels of Diacetyl in the finished beer if the lower growth rate results in lackluster fermentation.

It is often beers that ferment more slowly and produce less acetolactate that have Diacetyl problems, since the yeast are still slowly producing Acetolactate late into fermentation.

Besides ensuring yeast health and vigorous fermentation, sufficient maturation time and temperature are necessary for Diacetyl reduction.

(iii) Yeast & Fermentation

Diacetyl

Highly flocculent strains usually result in lower attenuation and increased levels of Diacetyl and esters. Medium flocculators tend to produce “cleaner” beers with lower levels of Diacetyl and esters.

Because the cells stay in suspension longer, they attenuate the beer more and reduce diacetyl and other fermentation compounds to a greater degree.

Highly flocculent English ale strains, are heavy Diacetyl producers.

Crashing the fermentation temperature early keeps the yeast from reducing Diacetyl.

The longer the yeast stay in suspension, the more time they have to reduce many intermediary fermentation compounds.

(iii) Yeast & Fermentation

Fusel Alcohols

Fusel alcohols such as n-Propanol, iso Butanol, and iso Amyl Alcohol can add warming, hot, or solvent flavours to beer. 9,10, 11,12

There are no beer styles where hot and solventy are desired traits.

Fusel alcohol concentrations increase with fermentation temperature

Fusel Alcohols are important in the formation of Esters.

More Fusel Alcohols = More opportunity for ester formation

(iii) Yeast & Fermentation

Acids

During fermentation, yeast also produce varying levels of organic acids such as Acetic, Lactic, Butyric, and Caproic. 13, 14

In most fermentations, the concentrations produced are below the flavour threshold, which is usually a good thing.

Lactic acid aside the other acids have flavours and aromas of vinegar, vomit, and barnyard animals.

However, these acids are necessary, as they play a key role in ester formation.

(iii) Yeast & Fermentation

Esters

Esters play a big role in the character of beer, especially in ales. 2,3, 15-23

An ester is a volatile compound formed from an organic acid and an alcohol, and it is esters that provide the fruity aromas and flavours that you find in beer.

Enzymes combine an alcohol with an activated acid.

The process of combining an acid and an alcohol to form an ester takes some time, since the yeast needs to create the alcohols first.

(iii) Yeast & Fermentation

Phenolic, Brettanomyces & Wild Yeast Strains

Phenolic compounds, which are hydroxylated aromatic carbon rings, can come from ingredients and from fermentation.

Phenol-based antiseptics contain them, which is why people often describe them as medicinal tasting.

Phenolic compounds can also be smoky and spicy.

They are less volatile than fusel alcohols, which means they stay in the beer throughout aging.

Once they are present at a detectable level, you will probably always taste them.

In most beer styles, phenolic flavours are a flaw, although there are some obvious exceptions.

(iii) Yeast & Fermentation

Phenolic, Brettanomyces & Wild Yeast Strains

Phenolic Ale Yeast Strains are traditional in Belgian-type ales and German weizen beers. Increased phenolic production is the characteristic that most brewers equate with Belgian yeast strains.

The German wheat beer strains produce a phenolic and ester character that is traditional. Without this spicy clove and fruity banana character, it would not be a German weizen.

Weizen must have clove, Rauchbier must have smoke, and some Belgian beers have other phenolic characters, but when phenols turn up unintentionally, it can be a disaster.

Most brewer’s yeast strains have a natural mutation in the POF gene preventing them from producing **4 vinyl guaiacol (4VG)**. In fact, the unintentional production of a phenolic character is a good indication that wild yeast has contaminated the beer.

However, Fermentation is not the only source of phenolic compounds. Sometimes the brewer adds them intentionally by using smoked malts, from the contact with oak or other woods from barrel aging.

(iii) Yeast & Fermentation

Phenolic, Brettanomyces & Wild Yeast Strains

Brettanomyces produces four key by-products: volatile organic acids, esterases, tetrahydropyridines, and volatile phenols.

One common acid they produce is **Acetic acid,** and we usually find that Brettanomyces beers with high levels of acetic acid also have high levels of the solvent like **Ethyl Acetate**. 3

Brett fermentation forms volatile phenols such as **4-ethylphenol (medicated) and 4-ethylguaiacol (burnt wood)**. 24, 25

Volatile phenols also produce spicy cinnamon, peppery, barnyard, horsey, and other classic Brettanomyces flavour compounds. 26

Other flavour-active, fatty acid-derived compounds common to Brettanomyces are **isovaleric, isobutyric, and 2-methylbutyric.** 27, 28, 29

(iv) Conditioning & Aging

Previously mentioned:

- Reduction in Diacetyl & Acetaldehyde
- Ester Formation
- Absorption of Phenolic compounds from barrel aging
- Oxidation effects

(v) Summary

The Mash
- Balance of Sugars
  - High Glucose
  - Ethyl Acetate
  - Isoamyl Acetate
- DMSO

Fermentation – Lag Phase
- Minimal Flavour Components

Fermentation – Growth Phase
- Sulphur Componds: DMS, SO2, H2S
- Alcohol & Fusel Alcohols
- Organic Acids
- Esters
- Phenolic Compounds

Fermentation – Stationary Phase
- Reabsorption
  - Diacetyl
  - Acetaldehyde
- Ester Formation
- Oxidation

Conditioning & Aging
- Ester Formation
- Phenolic Compounds from Barrel Aging
- Oxidation

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