

Off-Flavors from Bacterial Infections

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Portions adapted from *Brewery Bacterial Contaminants* by Moritz Kallmeyer

Gram-Positive Bacteria

Lactobacillus

These are a genus of catalase-negative, nonsporulating, rod-shaped organisms that are either homofermentative or heterofermentative, based on temperature tolerance and the mode of fermentation.

- * They constitute the predominant spoilage organisms in beer.
- * They are resistant to hop bittering compounds (isomerized alpha acids).
- * They are inhibited by high levels of alcohol (>6% ABV)
- * They can grow quickly - spoiling beer in just a few days or weeks.
- * All species produce lactic acid to some degree.
- * Serious infections result in a “crisp,” tart sourness which is mostly detectable in flavor, since lactic acid doesn’t volatilize

well.

- * Some species will produce diacetyl (“buttery”) compounds.
- * Spoilage can also be detected as a “silky” turbidity.
- * Spoilage is easily detected as loss of body (lactobacillus can metabolize dextrans, which brewers yeast cannot).
- * In infected bottle conditioned beers, lactobacillus organisms and increase carbon dioxide result in prolonged, slow gushing

from the bottle.

* Lactobacillus is desirable in Sour Beers (BJCP Category 17) - especially Berlinerweisse (17A). It is acceptable in low levels in Belgian Wit (16A).

Pediococcus

These are a genus of catalase-negative, homofermentative cocci that form characteristic pairs or tetrads due to their cell division in two planes. *Pediococcus damnosus* is the most common spoilage organism of the genus found in breweries that produce lager beer. The organisms are seldom found in the pitching yeast, but are found at times during the late fermentation or in the final beer.

- * *Pediococcus* infection causes high levels of acetic acid (vinegar) and diacetyl (buttery or butterscotch).
- * It is somewhat resistant to hop bittering compounds.
- * They can grow fairly quickly - spoiling beer in just a few weeks.

Gram-Negative Bacteria

Acetobacter

These are a family of rod shaped bacteria capable of producing acetic acid from ethanol. *Acetobacter* and *Gluconobacter* are two important genera under the group acetic acid bacteria that are traditionally associated with brewery fermentations. *Acetobacter* is known to oxidize ethanol to CO₂ and water via the hexose monophosphate pathway and TCA cycle. In the case of *Gluconobacter*, the hexose monophosphate shunt constitutes the most important route for sugar metabolism. The entire glycolytic and TCA cycles are not functional in *gluconobacter*.

- * They produce high levels of acetic acid - the active ingredient in vinegar.

* Acetic acid produces an intense, “harsh,” “lingering” vinegar-like sourness which is easily detected in aroma, since it volatilizes easily and is detectable at low sensory thresholds.

* *Acetobacter* are Aerobic bacteria, so they can only grow in the presence of oxygen. (e.g., barrel fermentation, plastic containers which are oxygen permeable, badly oxidized beer).

- * They are slow growing in beer and take weeks or months to develop.

* They are inhibited by high levels of alcohol (>6% ABV).

* Restrained *Acetobacter* character is expected in some sour beers (Flanders Red, Flanders Brown, Lambics).

* You have to really work to get *Acetobacter* in your beer! Not just bad sanitation, but also lot of oxidation of the fermenting wort and green beer and extended aging times. So, it’s not usually a problem.

Coliform Bacteria

This is a family of bacteria related to *Escherichia Coli*, AKA *E. Coli*. They are common water contaminants and are also commonly found in household environments (e.g., bathroom, kitchen sink).

- * They are inhibited by alcohol.

* They are inhibited by hop bittering compounds.

* They are inhibited by low pH (5.2 or lower).

* They grow very quickly.

* They produce sulfur-based compounds with aromas and flavors reminiscent of “barnyard,” feces, farts and “dirty dishrag.”

- * Under proper circumstances, they never appear in finished beer because the hops, alcohol, and reduced pH kill them.
- * Some forms of Coliform bacteria can cause illness. Historically, this is one reason why people drank beer instead of water - beer was guaranteed to kill the pathogens!
- * You have to really work to get Coliform bacteria infection!

Obesumbacterium proteus

The best-known brewery contaminant in the family Enterobacteriaceae is Obesumbacterium proteus. It is a gram-negative, nonacid-fast straight rod that can be found multiplying in the pitching yeast.

- * Can grow in unhopped wort. Inhibited by alpha acids.
- * Can tolerate pH values ranging from 4.4 to 9.0.
- * Can suppress the fermentation process!
- * Produces high levels of DMS, dimethyl disulfide, diacetyl and fusel alcohols.
- * Infected beer has a characteristic parsnip-like, vegetal and/or fruity odor.
- * Can grow relatively quickly.
- * Most common in sour mashes gone badly wrong.

Zymomonas

These are rods that occur mostly as single cells, in pairs, chains, or filaments, and most strains are non-motile. Motile strains have one to four flagella. Zymomonas mobilis is the most common brewery contaminant, and its most distinctive characteristic is the ability to convert glucose or fructose to ethanol and CO₂ via the Entner-Doudoroff pathway.

- * Inhibited by high levels of alcohol (>8% ABV).
- * Produces high levels of acetaldehyde (“green apple”) and hydrogen sulfide (“rotten eggs”) aromas and flavors.
- * Easily killed by heating (a few minutes of exposure to 60+ °C (140+ °F)).
- * Not a common infection organism. Occurs due to bad sanitation or sour mashes gone bad.

Megasphaera

Family of Coccus-shaped bacteria.

- * Imparts cloudiness.
- * Produces butyric acid (rotten cheese, vomit).
- * Rarely occurs.

Yeasts

Brettanomyces

A family of yeasts found naturally on grains, fruit skins, etc.

- * Not inhibited by hop bittering compounds.
- * Slow-growing compared to brewers yeast - can take weeks or months to develop.
- * Inhibited by alcohol (~ >6% ABV).
- * Can metabolize dextrans and starches, which brewers yeast cannot.
- * Produce characteristic “horsy,” “leathery,” “tobacco,” smoky and “goaty” notes.
- * Expected in Lambics. Very low levels acceptable in Old Ale (19A) as a point of complexity. Extremely low levels acceptable in Dry Stout (13A) and Foreign Extra Stout (13D) as a point of complexity.
- * Historically, a common spoilage organism in barrel-aged beers - especially from English brewers. Pre-20th century aged “stale” or “hard” beers, such as vatted porter, aged Burton ales, etc. would likely have had some Brett character.

Chemical name	Character	Percentage	Mixed with:	Concentration	Other Names
Acetic Acid - glacial	Vinegar	6.4%	DI-H ₂ O	270 mg/L	
Butyric Acid	Rancid butter, putrid	0.2%	20% ethanol	7.5 mg/L	
2-Ethyl fenchol	Earthy	0.004%	20% ethanol	15 µg/L	
Indole	Barnyard	0.015%	20% ethanol	0.55 mg/L	Benzopyrrole
Lactic Acid	yogurt, sour milk	8.3%	DI-H ₂ O	400 mg/L	DL-Lactic Acid
Octanoic Acid	Soapy, fatty, goaty	0.87%	40% ethanol	31.5 mg/L	Cyprilic Acid
2,3-Butanedione	Infection (Buttery)	0.005%	DI-H ₂ O	0.2 mg/L	Mixture
Acetic Acid	Infection (Sour)	4.3%	DI-H ₂ O	180 mg/L	Mixture

Inspirational Reading

- How to Brew*; John Palmer. Brewers Publications
- Radical Brewing*; Randy Mosher. Brewers Publications.
- Principles of Brewing Science*, 2nd Ed.; George Fix. Brewers Publications.
- Flavors in Beer* (<http://hbd.org/ford/judging/flavor.pdf>)
- Brewery Bacterial Contaminants*; Moritz Kallmeyer (<http://www.drayment.com/articles/arts/08.html>)
- BJCP Study Guide* (<http://www.bjcp.org/study.php>)