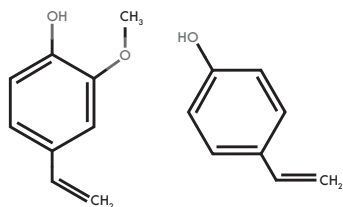




BEER OFF FLAVOR: PHENOLIC



A “phenol” is a class of chemical compounds containing a hydroxyl group (-OH) on an aromatic carbon ring. Because many compounds can be classified as a phenol, there is a wide occurrence of phenolic compounds in beer. Likewise, depending on the specific phenol there is a range of sensory descriptors when referring to phenolics in beer. This resource will focus on two major phenolic compounds originating from yeast metabolism: 4-vinylguaiacol (4VG) and 4-vinylphenol (4VP). However, readers should be aware that other phenols can be found in beer that are also considered a phenolic off flavor.

HOW DOES PHENOLIC SMELL OR TASTE?

The most common descriptors for 4-vinylguaiacol (4VG) are clove, curry, spice, smoky, and bacon with a sensory threshold of 100-300 ppb. Sensory descriptors for 4-vinylphenol (4VP) include phenolic, medicinal, and spicy with a similar threshold range as 4VG. The wild yeast genus, *Brettanomyces*, can produce additional phenols with flavor and aroma descriptors such as band-aid, barnyard, and horse blanket.

WHICH COMPOUNDS ARE RESPONSIBLE FOR PHENOLIC FLAVORS AND AROMAS?

4VG and 4VP are the volatile phenolic compounds most associated with phenolic aromas and flavors, however there are many other phenolic compounds with varying origins and sensory descriptors such as 4-ethylguaiacol, 4-ethylphenol, guaiacol, vanillin, and 4-vinyl syringol.

HOW ARE 4VG/4VP MEASURED?

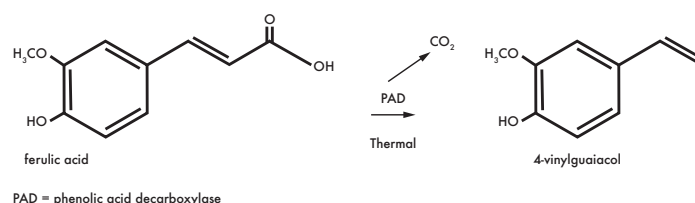
The most common and accessible way to detect 4VG and 4VP is through sensory analysis, preferably with a sensory panel trained on these attributes using spiked beer samples. More precise and analytical methods for detecting and quantifying phenols include analysis by gas and liquid chromatography; these methods are typically outsourced to third party labs since most breweries do not have the lab capabilities on site.

HOW ARE 4VG/4VP PRODUCED IN BEER PRODUCTION?

4VG and 4VP originate from malted barley and wheat which contain the precursors that are enzymatically converted by yeast into these two phenolic compounds. Ferulic acid is the precursor of 4VG, while *p*-coumaric acid is the precursor of 4VP. A ferulic acid rest during mashing (109-113°F/43-45°C) will increase the concentration of ferulic acid in the wort which increases the potential for 4VG production by yeast during fermentation.

The precursors are converted to 4VG or 4VP by either thermal or yeast-derived enzymatic decarboxylation (i.e., the removal of a CO₂ molecule from the chemical compound).

Thermal degradation occurs during the kettle boil, though its contribution is less than the enzymatic decarboxylation associated with many wild yeast strains, some production yeast strains, and some bacterial species. Yeasts that contain the gene coding for phenolic acid decarboxylase (PAD) is considered phenolic off-flavor positive, or POF+. Common yeast strains, such as some Belgian strains, can be used intentionally for their POF+ genetics to affect appropriate style characteristics and are not considered an off flavor in this case. Causes of misplaced phenolic flavors, or off flavors, are due to contamination of beer by wild yeast and bacteria, and cross contamination of POF+ production yeast. These microbes produce PAD that decarboxylate ferulic acid and *p*-coumaric acid present in wort and beer into 4VG and 4VP, respectively.



WHEN DOES 4VG/4VP BECOME AN OFF FLAVOR?

4VG and 4VP can be found in most beers below sensory detection levels, and becomes an off flavor when concentrations exceed the flavor threshold. Apart from styles that consider 4VG and 4VP a key flavor component, such as German-style wheat beers, rauchbier, and some saisons, detectable levels of these two phenols are considered an off flavor.

HOW IS 4VG/4VP CONTROLLED IN THE BREWERY?

The best way to keep phenolic off flavors, such as 4VG and 4VP, in check is by implementing and ensuring thorough cleaning practices throughout the brewing system. If a brewing strain becomes cross contaminated by a POF+ yeast strain, it is advisable to start a new propagation culture. If microbial contamination is not the cause of phenolic off flavors brewhouse

Continued >

practices should be examined. Mashing in at 149°F/65°C will reduce the amount of ferulic acid extracted from the malt. Reducing kettle boil times will avoid excessive thermal conversion of ferulic acid to 4VG.

Do:

- ❑ Validate effectiveness of CIP systems and document procedure frequency
- ❑ Evaluate cold side sanitary design (e.g., check piping for dead legs that can harbor wild yeast)
- ❑ Test beer for wild yeast contamination using selective media, PCR, or a third-party testing lab
- ❑ Evaluate brewing strains for contamination by wild yeast and POF+ brewing strains
- ❑ Perform sensory analysis to detect 4VG/4VP in finished product
- ❑ Replace gaskets and beer lines if wild yeast contamination is detected
- ❑ Monitor mashing temperatures

Avoid:

- ❑ Post boil ingredient additions that harbor wild yeast (e.g., fruits)
- ❑ Using yeast that are POF+ in the brewery without proper control and microbial evaluation strategies
- ❑ Excessive boiling

REFERENCES

1. Cui, Yunqian, Aiping Wang, Zhuo Zhang, and R. Alex. Speers. “Enhancing the Levels of 4-Vinylguaiacol and 4-Vinylphenol in Pilot-Scale Top-Fermented Wheat Beers by Response Surface Methodology.” *Journal of the Institute of Brewing* 121, no. 1 (2015-02-01 2015): 129-36.
2. Lentz, Michael. “The Impact of Simple Phenolic Compounds on Beer Aroma and Flavor.” *Fermentation* 4, no. 1 (2018-03-19 2018): 20.
3. Madigan, David, Ian Mcmurrough, and Malcolm R. Smyth. “Rapid Determination of 4-Vinyl Guaiacol and Ferulic Acid in Beers and Worts by High-Performance Liquid Chromatography.” *Journal of the American Society of Brewing Chemists* 52, no. 4 (1994-09-01 1994): 152-55.
4. White, Chris, and Jamil Zainasheff. *Yeast: The Practical Guide to Beer Fermentation*. Brewing Elements Series. Boulder, Colorado: Brewers Publications, 2010.
5. Williams, Stacey, and Justin Alexander. “A HS-SPME Arrow/GC-MS Method for Determination of Smoke Taint-Related Volatile Phenols in Humulus Lupulus.” *Journal of the American Society of Brewing Chemists* 80, no. 2 (2022-04-03 2022): 128-35.
6. Zhu, Mingguang, and Yunqian Cui. “Determination of 4-Vinylguaiacol and 4-Vinylphenol in Top-Fermented Wheat Beers by Isocratic High Performance Liquid Chromatography with Ultraviolet Detector.” *Brazilian Archives of Biology and Technology* 56, no. 6 (2013-12-01 2013): 1018-23.