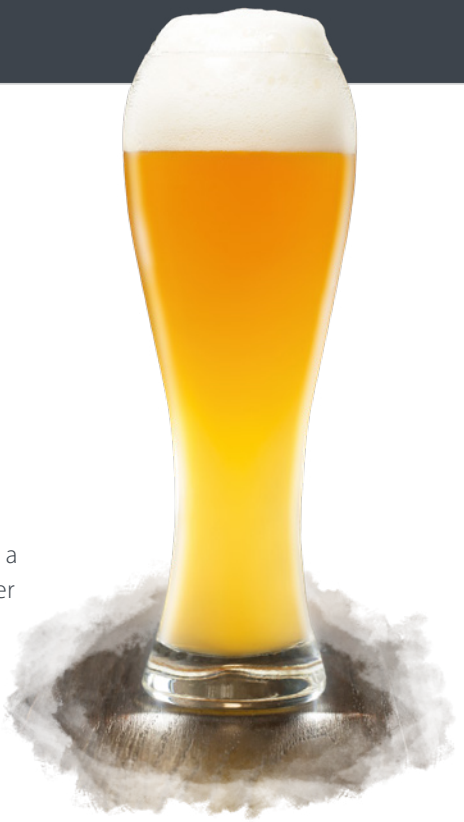
WHEAT BEER SOLUTIONS



Wheat beer is one of the oldest beer styles, dating back thousands of years. Wheat malt and unmalted flaked wheat impart unique characteristics to these styles such as increased body, a creamy mouthfeel, improved foam stability, and haze. There are many varieties of wheat beer that range in color from white to black, and alcohol content from 3-10% ABV. Within this diversity of styles, most wheat beer styles are united by the flavors imparted by specific yeast strains, notably banana (isoamyl acetate) and clove (4-vinyl-guaiacol, or 4VG) (Figure 1).

There are three main categories of wheat beer: German, Belgian, and American.

GERMAN WHEAT BEER

Weissbier, also known as *Hefeweizen* (*hefe* for "yeast" and *weizen* for "wheat") is the most popular German wheat beer style. *Weizen/Weissbier* is a refreshing wheat beer with high carbonation, naturally cloudy appearance, a full-bodied mouthfeel, low hop character, and a prominent and distinctive banana and clove yeast character. Brewers use from 50 to 70% malted wheat to achieve a very light color (2-6 SRM) .

Dunkelweizen (*dunkel* for "dark" and *weizen* for "wheat") is a darker wheat beer style made using darker kilned malts. The banana and clove character is prominent, but well balanced with the darker malts and wheat character. Hop rates are low.

Weizenbock is also darker in color, but with higher alcohol content up to 9% ABV. The typical banana and clove character of German wheat beer yeast is less prominent as it is overshadowed by the alcohol and higher malt character. Hop rates are low.

BELGIAN WHEAT BEER

Witbier (*wit* for "white"and *bier* for "beer") is an unfiltered ale that is naturally hazy due to the elevated level of wheat, and sometimes oats, used in the mash. Belgian *witbiers* are made with as much as 30-50% unmalted wheat and up to 5-10% raw oats.

Many *witbiers* have a complex herbal, spicy, or pepper character due to the addition of coriander, sweet or bitter orange peel, or other spices. Banana and clove character from the yeast is more subdued and balanced with the spice additions and wheat character. Hop rates are low.

AMERICAN WHEAT BEER

American Wheat Beer is similar in appearance to *Weizen/Weissbier* and *Witbier*, but with higher hop rates and a neutral yeast profile without any banana, clove, or spice character. 30–50% wheat malt is normally used in this style. Neutral American ale yeast or lager yeast are common, but moderate ester producing strains may also be used as long as banana and clove flavors are absent.

Beer style references: Hieronymus, 2010; BJCP Style Guide 2021

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Wheat Malt and Unmalted Wheat

Wheat is, of course, an essential ingredient for brewing wheat beers. In addition to imparting a grainy flavor and aroma, the higher protein levels of wheat compared to barley malt contribute to a creamy mouthfeel, and improved foam stability. Wheat contributes to the intense and stable haze that is an important characteristic of wheat beers. Wheat gluten proteins are haze active and interact with haze active polyphenols and protein-polyphenol complexes to form haze particles (Wang, 2021).

Wheat malt has higher levels of ferulic acid, which is the precursor for 4-VG. In general, beers brewed with wheat or wheat malt appear to generate higher levels of 4-VG than beers brewed with 100% barley malt. Studies have shown that 30% wheat or wheat malt is optimal for achieving higher levels of 4-VG in a wheat beer (Coghe et al, 2004). Wheat Malt has the typical malt enzymes and can be used at high rates up to 70%. Wheat Malt lacks a husk that is present on barley malt, which can result in slower lautering times when used at high rates (improved by adding rice hulls).

Unmalted wheat has no diastatic power on its own and provides a more intense grain flavor (bready flavor). It is used in many traditional Belgian styles to add flavor and haze, and improve head formation. Since unmalted wheat can release a lot of beta-glucan, which can cause mash lautering issues, it is better to restrict usage to under 15% (Hieronymus, 2010).

Flaked Wheat is lighter in color than wheat malt. It has been processed to partially break down starch and improve extraction yields. Due to its flaked form, it is not necessary to mill. Flaked malt can be used in moderate amounts up to 20%.

Wheat has a higher pH than barley, so pH control may need to be considered for wheat beer styles with high addition rates. *Acidulated malt* (also called acid malt or sour malt) may be used to reduce the mash pH to an optimal level. As a rule of thumb, using 1% acidulated malt in the grist will lower the pH of the finished beer by about 0.1. Acidulated malt will add more fullness of flavor to the finished beer and may increase the perception of citrus (Oliver, 2011).

MASHING METHODS FOR WHEAT BEERS

If enzyme-rich barley malt is being used, and the grist composition contains less than 50% wheat malt, a **single infusion mash** is possible. The barley malt should be very well modified, and the degree of protein solubility in the wheat malt should be above 40%. Rice hulls may also be used to improve lautering with when high levels of wheat are used.

If the malt used is not well modified, a **step-mash** is recommended in order to:

1. **Increases the level of free amino nitrogen available to the yeast.**
2. **Break down larger proteins to increase mash efficiency and improve lautering.**
3. **Improve flavor and mouthfeel.**

Ferulic acid is most often present in a bound (esterified) form in the grain cell wall and will be released by feruloyl esterase enzymes during the mashing process. These enzymes are most active at 45˚C and a pH of 5.8. A mashing rest at 45˚C can increase ferulic acid levels in the wort, and potentially increase 4-VG in the beer (Coghe et al, 2004).

The mashing process also affects the sugar composition of wort, which in turn affects the ester content. Isoamyl acetate levels can be increased by mashing at lower temperatures to increase the proportion of glucose, or by directly adding glucose (Yang et al, 2014). More complex step-mash procedures can be used to further optimize glucose to maltose ratios and boost isoamyl acetate levels (Eder, 2009).

The pH may be lowered by using acidulated malts or adding food grade lactic acid to the wort. Traditional German wheat beers were historically brewed using a sour mash method where lactic acid bacteria naturally present on the malt were permitted to sour the mash before lauter and boiling in the kettle.

Yeast Strain Selection

Traditional German and Belgian wheat beer yeast strains produce esters and phenolic compounds that are essential to the flavor profile. It is important to select a high-quality yeast strain that is appropriate for each wheat beer style.

Esters are formed intracellularly by an enzyme-catalyzed condensation reaction between an active acyl-coenzyme A (acyl-CoA) and an alcohol. The type of ester formed depends on the type of alcohol (Nordström, 1963 & 1964). The main volatile ester in all beers is ethyl acetate (fruity, or solvent-like at high concentration), which is formed from condensation of ethanol with acetyl-CoA (Verstrepen et al, 2004). Other esters are formed by the condensation of fusel alcohols. The most notable ester in wheat beer styles is isoamyl acetate (banana aroma), which is formed by the condensation of isoamyl alcohol. Wheat beer strains are known to produce higher levels of fusel alcohols, which then lead to higher ester levels due to the expression of alcohol acetyl transferase enzymes (Figure 1A).

The most notable phenolic compound in wheat beer styles is 4-vinyl guaiacol (4-VG), which is formed by decarboxylation of ferulic acid by thermal decomposition during wort boiling and by ferulic acid decarboxylase (FDC) enzymes during fermentation (Figure 1B). Yeast strains that produce FDC are referred to as POF+ (phenolic off-flavor positive), a term used since 4-VG is considered an off-flavor in commercial lager production.

For American Wheat Beers with high hop character, it may be desirable to choose a yeast strain that expresses biotransformation enzymes such as β-glucosidase and β-lyase in order to enhance the terpene and thiol aromatic profiles in the beer.

Some commercial wheat beer yeasts are known to be diastaticus (STA^+) and are able to metabolize dextrins, resulting in beers that are very dry with low body and a higher perception of acidity. For more full-bodied and creamy wheat beers, choose a yeast strain that is non-diastaticus (STA^-).

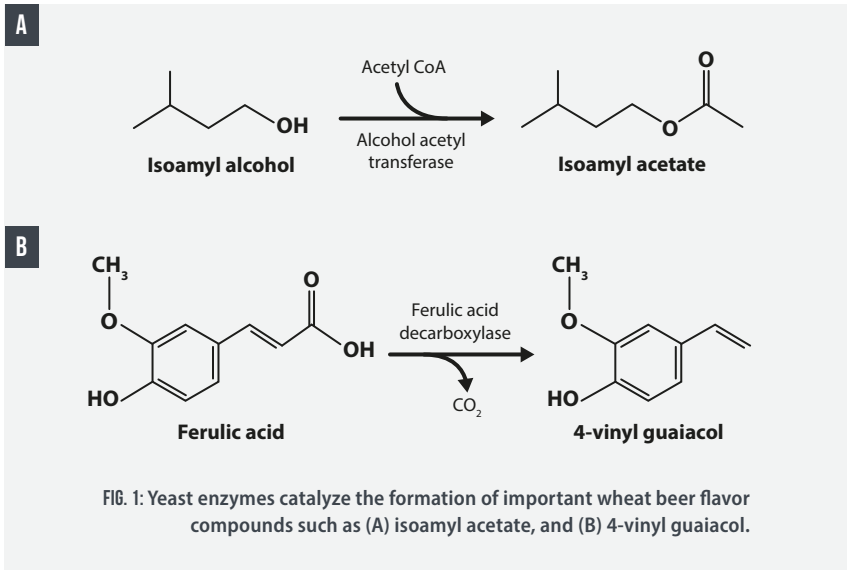


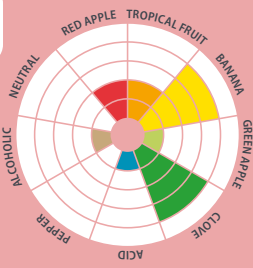
FIG. 1: Yeast enzymes catalyze the formation of important wheat beer flavor compounds such as (A) isoamyl acetate, and (B) 4-vinyl guaiacol.

STRAIN COMPARISON, QUICK FACTS, FLAVOR & AROMA

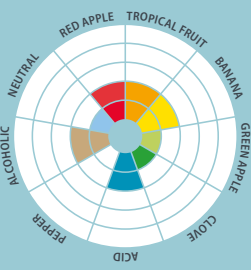
QUICK FACTS

	MUNICH CLASSIC WHEAT ALE YEAST	WIT BELGIAN WIT-STYLE ALE YEAST	FARMHOUSE HYBRID SAISON-STYLE YEAST	ABBAYE BELGIAN-STYLE ALE YEAST
ATTENUATION RANGE	78 - 83%	75 - 82%	78 - 84%	77 - 83%
FLOCCULATION	Low	Low	Low	Medium to high
TEMPERATURE RANGE	17 - 25°C (63 - 77°F)	17 - 25°C (63 - 77°F)	22 - 30°C (72 - 86°F)	17 - 25°C (63 - 77°F)
ALCOHOL TOLERANCE (ABV)	12%	12%	13%	14%
PITCHING RATE	50 - 100 g/hl	50 - 100 g/hl	50 - 100 g/hl	50 - 100 g/hl
DIASTATICUS (STA1)	Negative	Negative	Negative	Negative
BIOTRANSFORMATION	β-glucosidase: Medium β-lyase: Medium/Low	β-glucosidase: Low β-lyase: High	β-glucosidase: High β-lyase: Medium/Low	β-glucosidase: Medium β-lyase: High

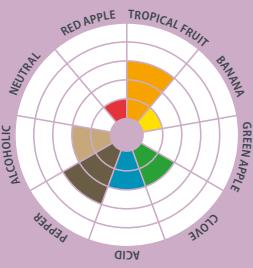
FLAVOR & AROMA



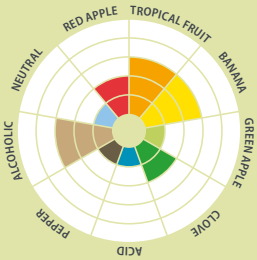
Fruity, banana, clove



Fruity, slight banana and clove



Clove, pepper, tropical fruit



Spicy, fruity, tropical, banana

STRAINS BY BEER STYLE	ABBAYE	BRY-97	FARMHOUSE	LONA	MUNICH CLASSIC	NEW ENGLAND	NOTTINGHAM	WINDSOR	WIT
AMERICAN WHEAT		✓		✓		✓	✓	✓	✓
DUNKELWEIZEN	✓		✓		✓				✓
WEIZEN/WEISSBIER			✓		✓				
WEIZENBOCK	✓		✓		✓		✓		✓
WITBIER	✓			✓			✓		✓

The traditional yeast recommendations for different wheat beer styles are shown in the table above. For American Wheat, nearly any POF-negative strain could be used depending on the desired level of esters. While not traditional, diastaticus saison strains such as LalBrew Belle Saison™ can be used to ferment very dry, lower body wheat beers. Very low, or non-alcohol wheat beers can be brewed using the maltotriose-negative strains such as LalBrew LoNa™, which is POF-negative and best suited for non-alcohol American Wheat, or Belgian Witbier styles.

FERMENTATION CONTROL FOR OPTIMAL FLAVOR

The most important flavor compounds for wheat beer styles, isoamyl acetate and 4-VG, can be influenced by controlling the fermentation conditions. Pitching rate and fermentation temperature are two variables that are easily controlled by the brewer to modulate the banana and clove character in the beer. We performed fermentations in the Lallemand R&D using a selection of LalBrew® wheat beer strains to determine how these flavor compounds are influenced by pitching rate and temperature.

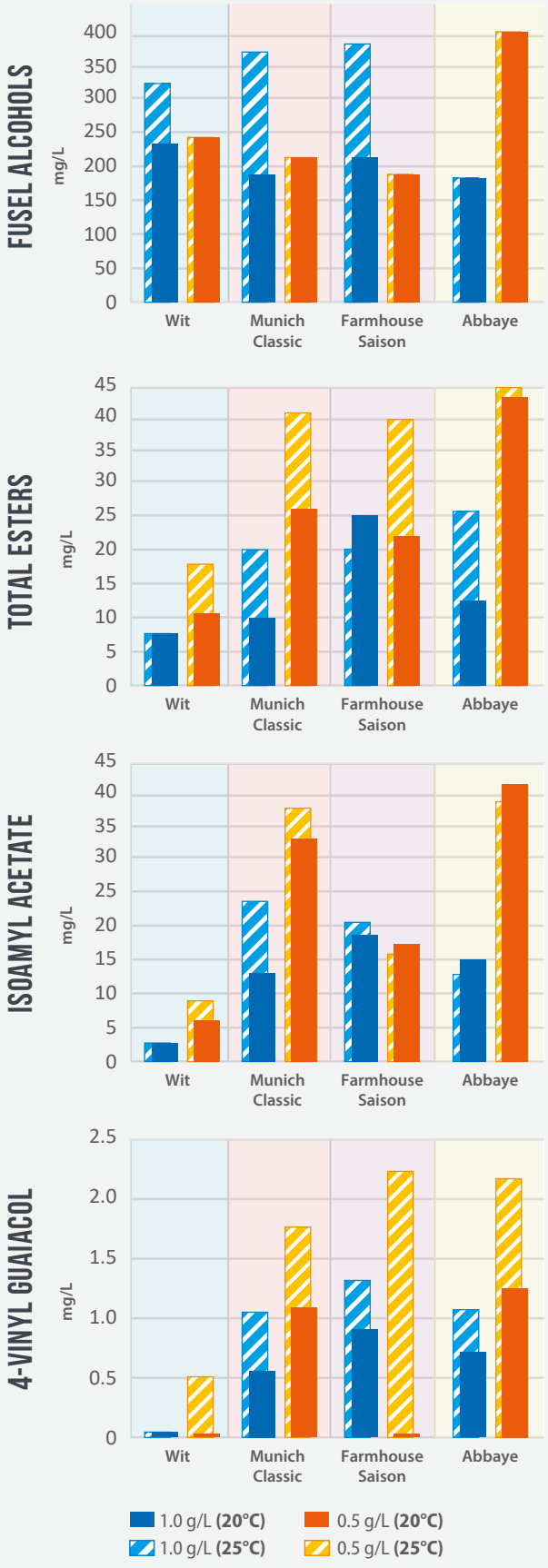


FIG. 4: Levels of important wheat beer flavor compounds in beers fermented with LalBrew® wheat beer strains. 12°P wort was pitched with 0.5 or 1.0 g/L of yeast and fermented at 20 or 25°C.

Esters and Fusel Alcohols

Fusel alcohol production is associated with greater yeast growth, which is encouraged by using lower pitching rates and higher fermentation temperature (Figure 4). Fusel alcohols are precursors for ester formation, so higher fusel alcohol production is associated with higher ester levels. Since fusel alcohols are reduced when esters are formed, the total fusel alcohols remaining in the fermented beer will depend on the metabolism of specific yeast strains. The highest fusel alcohol levels were observed when combining higher pitching rates with higher temperatures, with some exceptions depending on the yeast strain (Figure 4).

Higher total ester levels are strongly associated with lower pitching rates. Higher fermentation temperatures will also tend to increase total esters, but to a lesser degree than lowering the pitching rate. Lower pitching rates led to much higher levels of isoamyl acetate for LalBrew Munich Classic™ and LalBrew Abbaye™, moderately higher levels for LalBrew Wit™, but no significant change for LalBrew Farmhouse™ (Figure 4).

Ester levels may also be influenced by wort nutrition. Higher glucose levels (due to low mashing temperature or sugars additions), high gravity wort and higher levels of zinc will increase yeast growth resulting in more fusel alcohols and therefore more esters (Hiralal et al, 2014). Insufficient wort aeration or fermentation under pressure will tend to reduce yeast growth and lower total esters. The amount and type of specific esters produced will be strongly influenced by the specific yeast strain used.

Phenolics

4-VG levels are strongly correlated with lower pitching rates and higher fermentation temperatures. In most cases, 4-VG levels increase by roughly 1.5 to 2-fold when either fermenting at 25°C compared to 20°C, or by pitching 0.5g/hL compared to 1.0g/hL. A notable exception is for LalBrew Farmhouse™, where 4-VG levels are nearly zero when pitched at 0.5g/hL and fermented at 20°C, but reach very high levels at 25°C (Figure 4).

Haze control

The hazy appearance of wheat beer is related to many factors, such as grist (proteins, starch), yeast, and polyphenols suspended in the beer. Using > 20% wheat will normally achieve an intense and stable haze. Unmalted wheat can contribute to a starch haze in beer. Using highly modified barley malt will increase haze stability due to higher proteolytic activity, which leads to smaller protein particles that remain in suspension (Depraetere et al, 2012). Although low flocculation strains are generally used for brewing wheat beers, studies have shown that haze stability is related to the grist composition and not yeast flocculation.

QUICK REFERENCE - WHEAT BEER SENSORY CONTROL

	To increase	To decrease
Esters	Higher gravity wort Increase glucose ratio (lower mash temperature or adding sugars) Add nutrients (FAN, zinc) Avoid pressurized fermentation (open fermenter) Decrease pitching rate Choose a high ester yeast strain Increase fermentation temperature	Lower gravity wort Lower glucose ratio (higher mash temperature and avoiding sugar additions) Use higher levels of unmalted wheat Pressurized fermentation Choose a low ester yeast strain Increase pitching rate Decrease fermentation temperature Increase aeration rate
4VG	Use ~30% wheat or wheat malt Use well-modified malts Ferulic acid rest during mash (45 °C, pH 5.8) Use POF+ yeast Increase fermentation temperature Decrease pitching rate	Use <20% or >50% wheat or wheat malt Single infusion mash Use POF-negative or low POF yeast Decrease fermentation temperature Increase pitching rate
Body and Mouthfeel	Increase mash temperature Step mash Increase levels of flaked wheat Use special malts (i.e. Munich or dextrin malt)	Decrease mash temperature
Acidity	Use acidulated malt Sour mash Add food grade lactic acid Decrease ratio of wheat	Use non-diastaticus yeast

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