
LAGER BREWING
MADE EASY
From raw materials to process control, everything you need to know to brew your best lager.
LALLEMAND

INTRODUCTION

Lager is the most popular category of beer in the world. Its color and flavor vary from light pilsners to amber Vienna lagers and dark German Dunkels — but the brews all share a delicate, clean, and balanced flavor profile. Light lagers dominate this category to such an extent that the word "lager" is often used synonymously with light lager styles.

The recipe for lager brewing may appear simple, but the process can be more difficult than ales. Sensory defects cannot be masked by the complex flavors of malt and hops — laying bare every potential misstep in ingredient selection, sanitation, mashing, boiling, fermentation, maturation, and filtration.

Avoiding sensory defects requires high-quality ingredients, careful management of the brewing process, and stringent quality control.

This technical paper is a general reference for the most important control points to help you to craft consistent and high quality lager beers, with emphasis on pilsner and light lager styles (referred to as "lager" throughout for simplicity). The team at Lallemand Brewing combined our experience helping breweries of all sizes across the world to describe how to:

- **Select quality raw materials**, including yeast, water, malt, hops, and adjuncts
- **Maintain quality control** during the brewing process and avoid contamination
- **Control the brewing process** during mashing, boiling, fermentation, and maturation

Lager beers can vary in color and flavor. The most popular lager style is pilsner, which has a light golden color and a crisp, refreshing flavor. In fact, pilsners are so prevalent that the term is often synonymous with lagers.

SELECTING RAW MATERIALS 1/3

Quality and freshness of ingredients are important to achieving a crisp, light, and defect-free lager. Balance is the key. There is no single dominating flavor or aroma in a lager. The quality and characteristics of the water, malt, hops, and yeast all play an important role.

WATER

Like many traditions in brewing, the water quality and malt requirements are based in the history of the beer. The water in Pilsen, Czech Republic — which is the birthplace of the pilsner style — was historically low in minerals and salts including carbonates and sulfates. A soft water profile contributes to the clean flavor profile of lager beer.

Historically, the use of soft water was essential for brewing the first light pilsners. The base malts available were slightly darker (and therefore more acidic) than modern pilsner malts, and a decoction or step mashing method allowed brewers to achieve a pH suitably low for brewing beer without using darker kilned malts.

When using modern light pilsner malts, soft water and step/decoction mashing are not sufficient to lower the wort pH to an ideal range of 5.1 to 5.2. It is common to adjust the pH by using acidulated malt, blending sour wort produced in another vessel, or adding food grade acids (i.e. lactic or phosphoric).

MALT AND ADJUNCTS

Lagers typically use lightly kilned malts, in the range of 1 to 2 Lovibond or 1.5 to 2.0 SRM. It is important to select the highest quality malt, which is typically well-modified with high enzyme levels.

BUILDING OFF HISTORY:

TRADITIONAL WATER PROFILES

The water profile used to produce the first pilsners in Pilsen, Czech Republic, might have looked like this:

- Calcium (Ca), 10 ppm
- Bicarbonate (HCO_3), 5 ppm
- Sodium (Na), 2 ppm
- Magnesium (Mg), 3 ppm
- Chloride (Cl), 6 ppm
- Sulfate (SO_4), 8 ppm

Modern brewing best practice is to add calcium chloride ($CaCl_2$) to achieve Ca levels of >50 ppm to promote flocculation.

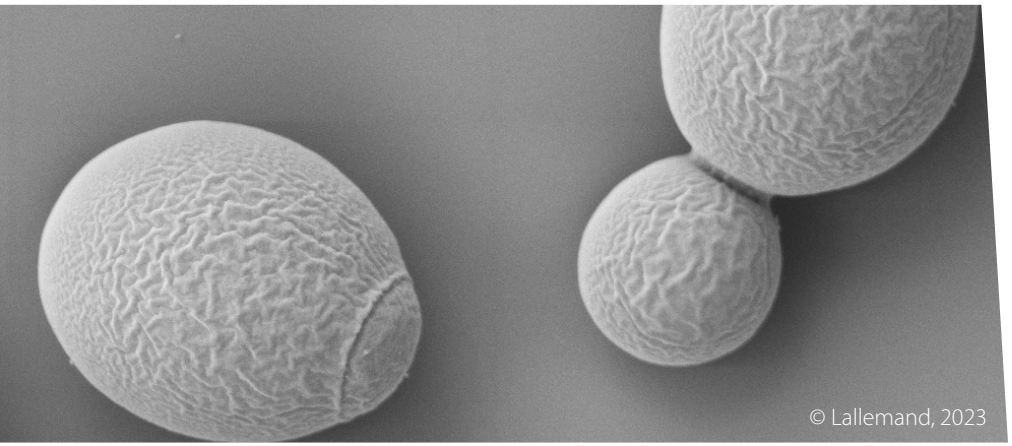
It is also common to use adjuncts such as rice or corn up to 15 to 20% of the malt bill without adding additional enzymes. The use of adjuncts will decrease body and lead to a lighter colored beer that is crisper and cleaner. High enzyme activity is particularly important when using adjuncts to ensure full conversion. Acidulated malt may also be used for pH control.

The use of adjuncts in lager brewing can have a tremendous impact on wort nitrogen levels. Adjunct worts have lower total free amino nitrogen (FAN) levels compared to all-malt worts. Therefore, you may need to use nutrients to supplement FAN levels in the wort and promote a healthy fermentation, especially when using adjuncts or for high gravity brewing.[1]

HOPS

Traditionally, brewers used locally available noble European hops such as Saaz, Hallertau, Spalt, and Tettnang to brew light lagers. For pilsner brewing, the emphasis should be on neutral and clean bitterness with aroma hops added at the end of boil. Dry hopping is not traditional for pilsner styles.

SELECTING RAW MATERIALS 2/3



YEAST

The most defining ingredient of the lager style is the *Saccharomyces pastorianus* yeast. All lagers are brewed with *S. pastorianus* — the original and traditional lager yeast.

S. pastorianus is a natural hybrid between *Saccharomyces cerevisiae* (ale yeast) and *Saccharomyces eubayanus* (a more cold-tolerant yeast). This hybridization is thought to have occurred sometime in the 16th century.[2]

S. pastorianus is a bottom fermenting yeast used for brewing lager style beers. It is distinct from the top fermenting ale yeast in its ability to ferment at cooler temperatures and to ferment specific sugars such as melibiose. The high attenuation of lager yeast leads to beers that are crisp and clean.[3]

Lager yeast strains are classified based on how much of their genome is derived from each parental species (Figure 1).

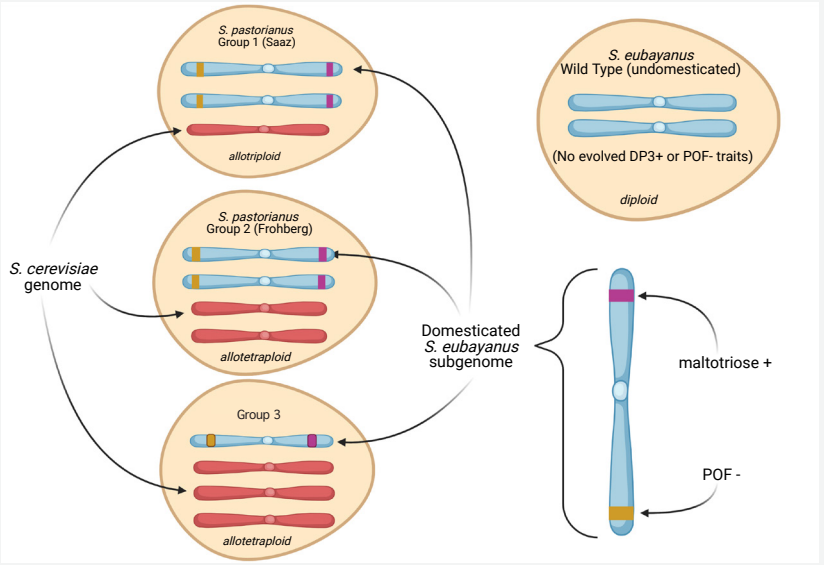


Figure 1: Comparative genomic structure of Group I (Saaz), Group II (Frohberg), and Group III (Renaissance) lager yeast strain lineages.

Group I (Saaz) lager strains have one set of chromosomes from *S. cerevisiae* and two from *S. eubayanus*. These strains are more cryotolerant due to the higher amount of *S. eubayanus* genome.

Group II (Frohberg) lager strains have two sets of chromosomes from *S. cerevisiae* and two also from *S. eubayanus*. These strains have robust fermentation characteristics compared to Group I, including broader temperature range and greater alcohol tolerance.[4]

Group III (Renaissance) lager strains have three sets of chromosomes from *S. cerevisiae* and one from *S. eubayanus*. With greater contribution from the *S. cerevisiae* genome, these strains can produce clean lagers with more ale-like fermentation characteristics including lower pitching rate, less diacetyl production and higher temperature tolerance compared to Group I and II.

SELECTING RAW MATERIALS 3/3

Group I and Group II strains produce very neutral flavored beers and there is very little genetic variation between these traditional strains.[5] Group III strains, on the other hand, were selected recently using classical (non-GMO) yeast breeding methods and are distinct from traditional lager strains.[6] The characteristics of Group III strains will vary depending on the parental strains used in their selection. Group III strains selected to possess the domesticated *S. eubayanus* genome instead of a wild *S. eubayanus* genome have been shown to efficiently ferment malt sugars with high attenuation and no POF flavors, making them well-suited to industrial lager beer production. The *S. cerevisiae* genome imparts unique flavors and fermentation characteristics to Group III strains that will vary depending on the specific parental strain used.

While not traditional, it is possible to produce pseudo-lager style beers with good results using neutral, cold-tolerant *S. cerevisiae* strain. In fact, several commercial lager yeast strains have been identified to be *S. cerevisiae* instead of *S. pastorianus*.[7]

MAINTAIN QUALITY CONTROL

Because of the neutral flavor of lagers, the style is deceptively challenging to brew. Off-flavors have nowhere to hide, and even small variations in the raw materials or brewing process can impact the flavor profile.

AVOID CONTAMINATION

Sanitation is important for all brewing styles. However, the delicate profile of lagers makes quality control critical.

Focus on these FIVE QUALITY CONTROL PROCESSES:

1. Robust cleaning and sanitation procedures
2. Yeast viability and cell count
3. Testing for the presence of bacteria and wild yeast
4. Detecting diacetyl and other vicinal diketones (VDK)
5. Implementing a sensory program

FLAVOR CONTROL

The clean and light flavor of lager beers leaves nowhere for off-flavors to hide. As a result, it is critical to control the brewing process to avoid off-flavors and maintain product quality. A well-trained sensory panel is a simple and effective tool for detecting off-flavors during the brewing process and ensure high quality and consistent lager beer. Early detection of off-flavors can facilitate corrective actions and may save your brew!

FOCUS QUALITY CONTROL ON COMMON CONTAMINATION ZONES

Common sources of contamination in brewing can include poorly cleaned and sanitized equipment, including:

- Heat exchanger
- Fermenters
- Filling lines
- Valves
- Dead ends
- Gas pipes
- Bottles

Re-pitched yeast can also be a source of contamination in subsequent fermentations.

Secondary contamination accounts for about half of all incidents of microbiological spoilage in breweries. Sources of secondary contamination include all points with direct or indirect contact with cleaned or filled unsealed bottles.[8]

Ensure that the tasters on your panel are trained to detect the most common off-flavors in lager beers, including DMS, diacetyl and H_2S. Sensory data can help to identify potential problems with raw ingredients, equipment or the brewing process.

We will discuss below how to effectively prevent and control these off-flavors by ensuring effective boiling of the wort and proper fermentation and yeast management.

PROCESS CONTROL: MASHING 1/3

Lager beer recipes often include higher amounts of adjuncts and light pilsner malts that are less modified and/or of poor quality. Additional mashing steps are required to ensure full starch conversion. A modified mash procedure gives you full control of the mashing process and helps to improve fermentation and beer quality. A traditional lager mashing includes multiple rest times at progressively increasing temperatures. Historically, this was achieved using a process called decoction, whereas most modern lager breweries use a heated mash tun to achieve a stepped-temperature mash. Depending on the quality of the malt, grist composition, or personal preferences for traditional brewing methods, you might choose one of three mashing techniques.

STEP MASH

The purpose of a step mash is to provide rest periods at different temperatures to promote the activity of specific enzymes. A heated mash tun is required to raise the temperature for each rest period. Each temperature step has a specific function:

An **acid rest** at 35°C (95°F) allows phytase enzymes in the malt to lower the pH by releasing phytic acid into the wort. This step may be skipped if the pH is lowered by using acid malt or adding food-grade acids.

A **β-glucan rest** at 40 to 50°C (104 to 122°F) allows β-glucanase enzymes to break down β-glucans to reduce wort viscosity, improve filtration times, and increase extract yields. This step may be required when using lower quality malts with higher levels of β-glucans. β-glucans can also be reduced by adding glucanase enzymes to the mash.

PROCESS CONTROL: MASHING 2/3

A **protein rest** at 45 to 55°C (113 to 131°F) allows proteolytic enzymes derived from the malt to break down larger proteins into smaller peptides and amino acids. This results in higher levels of FAN in the wort, which is essential for a healthy and vigorous fermentation.

A protein rest is especially important when using poor quality malt or higher levels of adjuncts. Historically, a protein rest was necessary to increase the amount of FAN derived from the lower quality malt available at the time. A neutral protease enzyme may be added to increase protease activity during this step. FAN may also be increased by simply adding an appropriate brewing nutrient.

The acid, β-glucan, and protein rests are followed by the usual **saccharification rest** between 62 to 66°C (143 to 150°F) where α- and β-amylases break down starch into smaller fermentable sugars. The saccharification rest is held until full starch conversion is achieved, usually 45 to 60 minutes, but may be more depending on the recipe. When using high adjunct levels, especially raw ungelatinized grains, the temperature may be raised to 72°C (162°F) to allow better starch liquefaction, promote α-amylase activity, and ensure full conversion.

A **mash out** step is performed by raising the temperature to 78°C (172°F) to inactivate enzyme activity and ensure that saccharification is arrested prior to starting the sparge/lauter. The increased temperature also lowers viscosity for easier lautering.

A typical step mash procedure is shown in Figure 2. The exact temperatures and times for a step mash can vary depending on the raw materials and enzymes used.

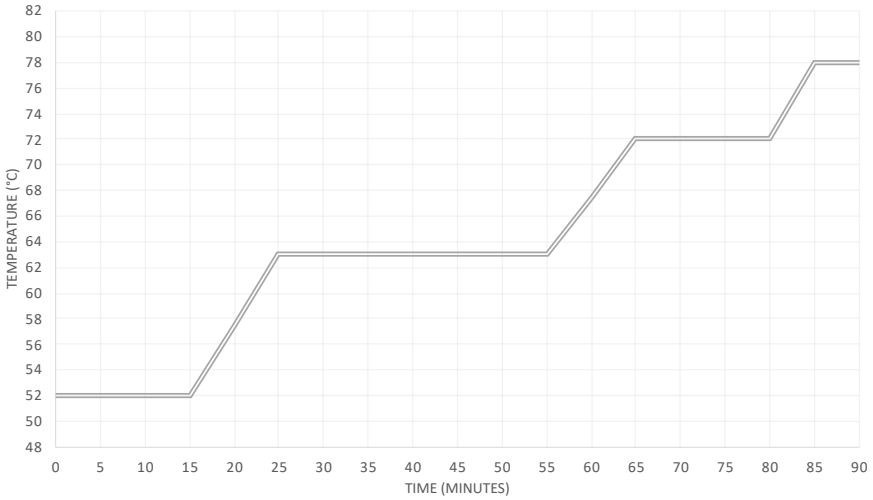


Figure 2: A typical step mash temperature profile

DECOCTION

With decoction mashing, the temperature is increased by removing a portion of the mash to boil before returning it to the mash tun. This was the traditional method used by lager brewers long before modern equipment was invented.

Decoction helps to increase extract from poorly modified malt. A side effect of decoction is that browning reactions occur during the boiling of the thick part of the mash. This gives the wort distinct flavor notes. Moreover, changing the duration of the boiling, brewers could get different flavor profiles from slightly grainy to the flavor of bread crust, toffee, and caramel.

There are two schools of thought on the best mashing method for lager styles. Some say that a traditional decoction gives lagers their unique character. On the other hand, many modern brewhouses view this step as a waste of time and the flavors imparted by traditional decoction can be more easily achieved using specific malts currently available on the market.

PROCESS CONTROL: MASHING 3/3

SINGLE INFUSION MASH

While not traditional, it is possible to brew lagers using a single infusion mash if using high quality malts. However, this process is more likely to require the use of food grade acids, enzymes, and other process aids to achieve the same results.

Greater attenuation may be achieved through addition of glucoamylase or alpha-amylase enzymes to the mash if using adjuncts such as rice or corn with a single infusion mash.

MASHING ENZYMES

The addition of enzymes during the brewing process can improve process efficiency, yields, and product quality. Enzyme additions are particularly useful when using lower quality malt or higher levels of adjuncts, in particular raw grains such as rice and corn.

Glucanase may be added to the mash to break down β-glucans and improve filtration speeds by reducing wort viscosity.

Glucoamylase may be added to the mash or fermenter to break starches and dextrins into glucose to increase attenuation.

Alpha-amylases may be added to the mash to reduce wort viscosity and increase wort fermentability.

HOW TO CHOOSE A MASHING METHOD?

STEP MASH:

- Requires temperature control for mash tun
- Allows for use of poor-quality malt (low FAN)
- Allows for higher adjunct rates compared to single infusion
- Adjuncts must be sugars or gelatinized grains (flaked rice or corn)

DECOCTION:

- Historical technique
- Requires additional equipment
- Allows for higher adjunct rates compared to single infusion
- Allows for use of poor-quality malt or raw (ungelatinized) adjuncts such as rice or corn
- Begins process of reducing DMS
- Imparts flavor due to browning reactions
- High energy consumption

SINGLE INFUSION:

- Requires high-quality malt
- Low amounts of gelatinized adjuncts (flaked rice or corn) are acceptable.
- May require enzymes and/or process aids if using ungelatinized grains.

PROCESS CONTROL: BOILING

DMS IS REDUCED WITH A VIGOROUS BOIL

The boil is an essential step in any beer style production. For Lager production, vigorous boiling is especially important for flavor control due to its role in the formation and removal of dimethyl sulfide (DMS).

DMS is found in all beers. At threshold levels, it can enhance the malty character. In higher concentrations, it results in a cooked corn or vegetable aroma.

DMS is formed from the precursor S-methyl methionine (SMM), which is derived from malt. SMM will degrade under heat in the kettle to form DMS. This reaction is more rapid at a higher pH, so acid additions to the kettle should be done at the end of the boil to promote the conversion of SMM to DMS. The DMS formed is volatile and eliminated through a vigorous boil with a well vented kettle. Wort should be cooled quickly after boil to prevent the formation of additional DMS from SMM degradation.

The lightly kilned malts used to make pilsners contain higher levels of SMM compared to pale malt. As a result, lagers are at greater risk of having higher levels of DMS due to the greater concentration of the precursor. To ensure all SMM is converted and DMS eliminated, a longer boil of 60 to 90 minutes is recommended for light lager styles.

DMS FLAVOR CONTROL

To avoid DMS in the finished beer:

- Select high quality malts with low SMM concentrations
- Boil vigorously for 60 to 90 minutes
- Ensure adequate kettle ventilation
- Avoid acid additions at the start of boil
- Cool the wort rapidly after boil

PROCESS CONTROL: FERMENTATION & YEAST MANAGEMENT 1/6

FERMENTATION TEMPERATURE AFFECTS OFF-FLAVORS

Traditional lagers were fermented at cool temperatures to produce a clean, neutral flavor profile, typified by low levels of esters and fusel alcohols. Historically, this was accomplished by using underground caves for fermentation and extended maturation times.

Most commercial lager fermentations are in the range of 8 to 12°C (46 to 54°F). Since yeast multiplication and metabolism is slower at lower temperatures, the yeast produces lower levels of acetaldehyde, H_2S and α-acetolactate (the precursor for diacetyl). However, these compounds are also less volatile at lower temperatures so less is driven off by CO_2 during fermentation. At lower temperatures, the rate of spontaneous decarboxylation of α-acetolactate to form diacetyl is reduced and reabsorption of diacetyl, acetaldehyde, and H_2S by the yeast is slower.

The traditional lager flavor profile allows for only very low threshold amounts of these compounds. As a result, lager beers normally have longer maturation times to ensure these off-flavors are reduced to a minimum to achieve the cleanest beer possible.

Fermentation at warmer temperatures above the optimal range for lager yeast can result in stress responses and the development of very high levels of these off-flavors, which may not be efficiently removed completely even after very long maturations. It is simpler to avoid the production of off-flavors in the first place by providing the yeast with optimal fermentation conditions.

When selecting a lager yeast strain, consider the propensity to produce diacetyl and H_2S. Choosing a strain known to produce lower levels of off-flavors even at higher fermentation temperatures will give you peace of mind in the event that your fermentation temperature control malfunctions. The LalBrew NovaLager™ strain in particular has an interrupted sulfur metabolic pathway that inhibits the normal formation of H_2S.

Consult your yeast producer or distributor for guidance on yeast strain selection.

PROCESS CONTROL: FERMENTATION & YEAST MANAGEMENT 2/6

PITCHING, HARVESTING & RE-PITCHING

Most lager fermentations require a significantly greater quantity of yeast compared to ale strains due to the cooler fermentation temperature. For lager strains, it is generally necessary to pitch 1 to 1.5 million cells/°Plato of wort. It is common practice to pitch the yeast into wort at a cooler temperature (around 10°C or 50°F) and then allow the temperature to rise by about 2°C (4°F) to reach the primary fermentation temperature.

An adequate pitch rate ensures:

- Vigorous fermentation
- Full attenuation
- Reduced off flavors

When re-pitching, harvest the yeast as early as possible to get the highest viability and avoid autolysis. In practice, this is normally done 24 to 48 hours prior to achieving full attenuation. It may be possible to harvest earlier if the slurry is dense enough to avoid beer losses. This depends on the beer style, its original gravity (OG), and the fermentation speed.

Recommendations for lager yeast re-pitching are the same as with ales. The maximum number of generations depends on yeast handling and sanitation procedures. The optimal number of generations is around 4 to 5 in order to reduce the risk of contamination or yeast mutation. However, this number can be raised to 8 to 10 generations by using good best practices for harvesting and storing yeast, measuring yeast viability and vitality, and also paying maximum attention to cleaning procedures. This ensures consistent fermentation performance and product from batch after batch, which is especially important for lagers. Using further generations of yeast is not recommended since it may lead to changes in flavor and might even cause flocculation and attenuation issues.

If yeast is stored before the next usage, it should be collected into clean and sterile vessels and stored at 2 to 4°C (35 to 39°F) for no longer than three days. The viability of the yeast should be determined at harvest and again before pitching. A common recommendation is for viability to be greater than 95%.

RE-PITCHING TIPS

- Store slurry at 2 to 4°C (35 to 39°F) for no more than three days.
- Measure cell count (usually 1 to 1.5 million cells/ml/°P) and viability (>95%) prior to pitching.
- Limit re-pitching to 8 to 10 generations.

For more information, see the Lallemand Brewing Repitching Best Practices document available here.

HARVEST YEAST LIKE A PRO

- Discharge the yeast slowly to avoid cone slippage and mixing of yeast layers.
- Discard the lower, dark layer containing dead cells and other sediments.
- Harvest only the middle, light, and creamy-colored layer of yeast. It has more robust and viable cells that will perform well in future fermentations.
- Avoid collecting the upper layer of small, light-colored cells. These are slow fermenting and low flocculating cells.

PROCESS CONTROL: FERMENTATION & YEAST MANAGEMENT 3/6

DIACETYL IS FORMED AND REABSORBED BY YEAST

Diacetyl is a common fermentation byproduct that is perceived by most people as an off flavor. At concentrations greater than 0.1 to 0.2 ppm, it can add the aroma of butter or butterscotch and give an oily sweetness to the beer.

Diacetyl is a byproduct of valine and leucine biosynthesis in yeast. During this process, α-acetolactate is formed as an intermediate and excreted into the fermenting beer where it spontaneously and non-enzymatically degrades into diacetyl. Diacetyl may then be reabsorbed by the yeast and further reduced to acetoin, a flavorless compound (Figure 3).

The quantity of α-acetolactate produced by the yeast is a strain-dependent characteristic.[9] Ale strains have higher valine uptake rates compared to lager stains and, therefore, have lower rates of endogenous valine production and lower production of diacetyl. Lager yeast lineages with a greater proportion of S. cerevisiae in their sub-genome tend to produce lower levels of diacetyl.[10]

Production of α-acetolactate is increased when valine biosynthesis is more active. This is the case when amino acids are lacking in the wort, therefore FAN-deficient wort increases α-acetolactate production. A low pitch rate will result in more yeast multiplication and a greater need for amino acids, so valine biosynthesis and α-acetolactate production are greater with low pitch rates.

The spontaneous decarboxylation of α-acetolactate is more efficient at warmer temperatures and a lower pH (4.2 to 4.4). Diacetyl reabsorption by the yeast takes time and is faster at warmer ale temperatures compared to cooler lager temperatures. Therefore, a longer period in contact with the yeast is required, often through a diacetyl rest, to reduce this compound in lager beers (Figure 4).

Diacetyl formation can be inhibited by using an acetolactate decarboxylase enzyme (ALDC). ALDC helps convert α-acetolactate directly to acetoin and bypass the formation of diacetyl as an intermediate (Figure 3). The reduced formation of diacetyl results in a reduced maturation time and an increased maturation capacity in the brewery.[11]

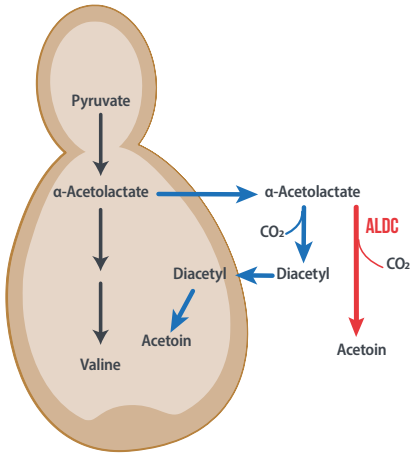


Figure 3: The addition of α-acetolactate decarboxylase (ALCD) enzyme allows the direct breakdown of α-acetolactate into flavorless acetoin (red lines) and prevents the formation and normal metabolism of diacetyl by the yeast cell (blue line).

PROCESS CONTROL: FERMENTATION & YEAST MANAGEMENT 4/6

AVOID DIACETYL BY PERFORMING A DIACETYL REST

A diacetyl rest is often used at the end of fermentation to promote yeast activity and reabsorption of diacetyl. To perform a diacetyl rest, increase the temperature of fermentation by 2 to 4°C (4 to 7°F) towards the end of fermentation when yeast is still actively fermenting (approximately 65 to 75% of full attenuation). Hold this temperature for up to two days after full attenuation, depending on the amount of diacetyl in the beer.[12]

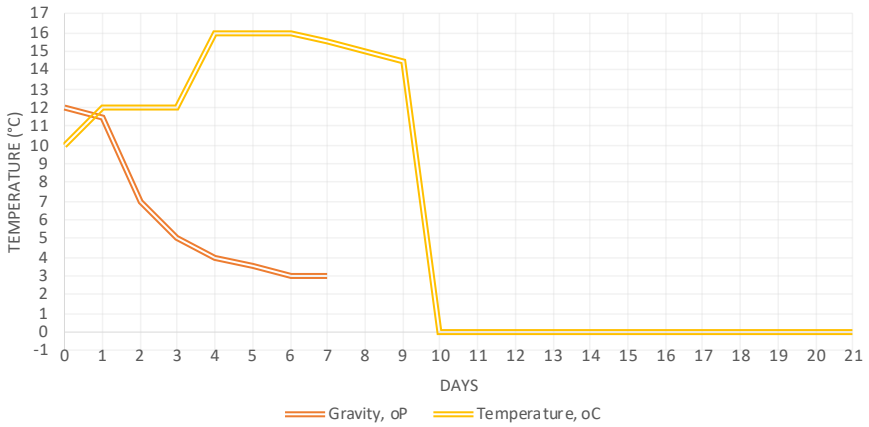


Figure 4: A typical diacetyl rest is performed by increasing the temperature for several days at the end of active fermentation.

DIACETYL FLAVOR CONTROL

TO REDUCE DIACETYL LEVELS:

- Ensure sufficient wort nutrition. FAN levels can be increased by doing a protein rest, adding a neutral protease enzyme and adding nutrients.
- Select a yeast strain that produces lower levels of diacetyl.
- Ensure an adequate pitching rate of highly viable yeast.
- Perform a diacetyl rest at the end of fermentation.
- Give the beer sufficient contact time with the active yeast prior to transfer.
- Using an acetolactate decarboxylase enzyme (ALDC).

The beer may be cooled immediately after diacetyl and α-acetolactate levels are below threshold levels. This can be measured using gas chromatography or through sensory after performing a forced diacetyl test where a sample is heated to force conversion of α-acetolactate to diacetyl in the beer.

Diacetyl may also be produced by some species of bacteria, including *Pediococcus*. It may be difficult to differentiate diacetyl production from bacteria versus spontaneous decarboxylation of α-acetolactate left in the beer. Yeast fermentation results in the production of diacetyl as well as 2,3-pentanedione through a similar metabolic pathway. Bacterial fermentation, on the other hand, will only produce diacetyl.

These compounds can be quantified using gas chromatography. The presence of diacetyl and absence of 2,3-pentanedione indicates bacterial activity. Gas chromatography is expensive, which is why a diacetyl rest is important to minimize the chance of unconverted α-acetolactate remaining in the beer and converting to diacetyl spontaneously in the packaged product.

PROCESS CONTROL: FERMENTATION & YEAST MANAGEMENT 5/6

REDUCE H_2S BY CONTROLLING FERMENTATION AND ENSURING YEAST HEALTH

The flavor of boiled or rotten eggs in beer is a sign of hydrogen sulfide (H_2S), a highly volatile compound naturally occurring during any fermentation. Sulfur metabolism is a dynamic process, and H_2S levels rise and fall over the course of fermentation (Figure 5). H_2S is produced by normal yeast metabolism when sulfate ions are reduced for processing into amino acids. Alcoholic fermentation results in an accumulation of hydrogen ions (H^+) in the yeast cell. This acidic environment is stressful to the yeast. H_2S is produced by the yeast to process and remove excess hydrogen ions from the cell. Yeast will reabsorb H_2S at the end of fermentation, resulting in a decrease in H_2S levels in the beer. Reabsorption of H_2S by the yeast is promoted by raising the temperature at the end of fermentation and leaving the beer in contact with the yeast for a sufficient time before cooling and transfer.

The production of high concentrations of H_2S can occur during alcoholic fermentation because of yeast stress, which could be caused by:

- Poor yeast viability
- Insufficient pitching rates
- Wort nitrogen deficiency
- Fermentation temperatures that are too low

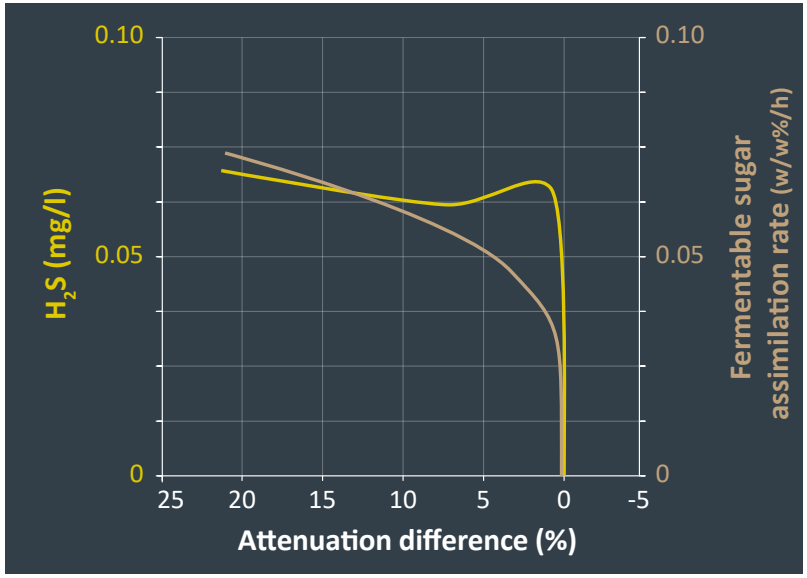


Figure 5: Typical pattern of H_2S behavior and yeast in suspension during fermentation.[13]

H_2S FLAVOR CONTROL

TO REDUCE H_2S LEVELS:

- Ensure an adequate pitch rate of healthy yeast.
- Use a balanced nutrient containing nitrogen, vitamins, and minerals.
- Give the beer sufficient contact time with the yeast at the end of fermentation.
- Avoid contact with oxygen in late stages or after fermentation is complete.

PROCESS CONTROL: FERMENTATION & YEAST MANAGEMENT 6/6

Different yeast strains vary in their response to physiological and environmental factors in the production and reabsorption of H_2S. It is important to understand the nutritional requirements of your yeast strain and to choose a yeast strain that is known to produce less H_2S.[14] Additionally, modern breeding methods have been used to produce brewing yeast with disrupted sulfur metabolic pathways that prevent the formation of H_2S.

The introduction of oxygen during late fermentation, beer transfer, or packaging is associated with increased H_2S levels in the finished beer. The introduction of oxygen after fermentation is complete may result in the yeast being stimulated to reactivate metabolism in a nutrient depleted environment, resulting in H_2S production.

FREE DOWNLOAD:
HYDROGEN SULFIDE & BEER TECHNICAL PAPER

This resource from Lallemand Brewing will help you understand more about H_2S, including:

- The composition of hydrogen sulfide
- How it is produced during brewing
- How failure to remove H_2S can result in formation of other, more stable, sulfur compounds
- Detection methods
- Prevention tips
- Techniques to remove H_2S

PROCESS CONTROL: ENZYMES & PROCESS AIDS 1/2

ENSURE QUALITY AND CONSISTENCY

A well-crafted pilsner is expected to be crystal clear and consistent. The use of adjuncts in this style presents a challenge to producing clear beer that is shelf stable, and consistency is elusive since defects cannot hide within a lager's delicate flavor profile. Since lager is often produced in high volumes, production time and process efficiency need to be considered more closely.

Enzymes and process aids are commonly used when brewing lager beer as they can increase efficiency, reduce waste, and improve the overall quality, stability, and profitability of the product.

BEER FININGS

Beer fining agents facilitate clarification by significantly increasing the speed of sedimentation of particles in the beer. They do this by binding to haze-causing particles and increasing their size, which results in proportionally faster sedimentation. There are many options to choose from, including:

- Isinglass
- Silica acid sols
- Auxiliary finings
- Pectin finings

ANTIOXIDANTS

Antioxidants function by scavenging dissolved oxygen and blocking staling reactions. It slows the formation of these off-flavors by blocking the formation of causative carbonyl compounds, particularly trans-2-nonenal, resulting in improved flavor and colloidal stability and slower rates of oxidative color development (browning).

SPOTLIGHT ON: CARRAGEENAN KETTLE FININGS

Carrageenan is added to the kettle at the end of the boil where it forms a random coil and reacts strongly with soluble proteins. Once cooled, the carrageenan adopts a more helical formation and the carrageenan-protein complex forms a gel, which precipitates out of solution, removing the protein's ability to later combine with polyphenols and cause a haze.

Carrageenan can also improve hot trub compaction in the whirlpool, which reduces waste and improves filtration efficiency.

BETTER BREWING WITH ENZYMES & PROCESS AIDS

Learn more about the many enzymes and process aids available for brewing lager beers.

Antioxidants are soluble in water and can be added to the mash vessel to guard against malt lipid oxidation or added just before filtration to scavenge any oxygen introduced during packaging.

STABILIZERS

After packaging, beer may tend to form haze through the interaction of polyphenols with haze-causing proteins rich in the amino acid proline.

The time required for proteins to bind and for the resulting haze to become visible determines the shelf life of the beer. Beer stabilizers are employed to inhibit this process by disabling or breaking down these components to prevent haze. The result is better flavor and visual stability and an increased shelf life.

PROCESS CONTROL: ENZYMES & PROCESS AIDS 2/2

ACETOLACTATE DECARBOXYLASE (ALDC)

The formation of diacetyl can be inhibited by using an acetolactate decarboxylase enzyme (ALDC), which converts α-acetolactate directly to acetoin (Figure 3). The reduced formation of diacetyl results in a reduced maturation time and an increased maturation capacity in the brewery. The activity of ALDC is pH dependant and will not work efficiently at the pH of a fully fermented beer (3.9-4.2), so it cannot remove diacetyl from a finished beer. For this reason, ALDC must be added to the wort at the start of fermentation when the pH is higher and valine biosynthesis is occurring during yeast multiplication.

CONCLUSION

Hundreds of years ago, lager brewers developed recipes and methods to make pilsner beer -- the world's most popular beer style. The development of modern lager yeast strains, enzymes, and process aids have made lager brewing easier and more efficient. Through careful control of the brewing process and by implementing a simple sensory panel to detect off-flavors, you can achieve consistently high quality lagers.

Whether you are a large multinational brewery, a smaller craft brewery, or a homebrewer, lager brewing has never been more accessible.

Discover Lallemand Brewing solutions for brewing lager beers. Details below.

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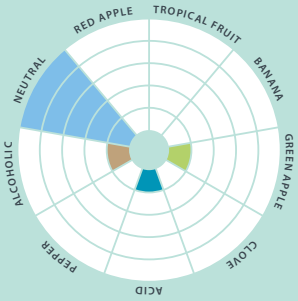
LALBREW® PREMIUM SERIES STRAINS FOR LAGER STYLES.

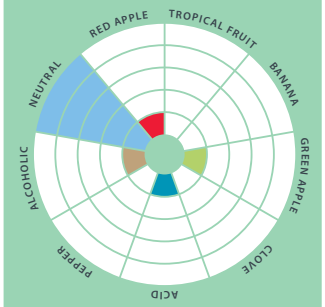
QUICK FACTS

	DIAMOND LAGER YEAST	NOTTINGHAM HIGH PERFORMANCE ALE YEAST	NOVALAGER MODERN HYBRID LAGER YEAST
SPECIES	*Saccharomyces pastorianus*	*Saccharomyces cerevisiae*	*Saccharomyces pastorianus*
LAGER CLASSIFICATION	Group II (Frohberg)	Pseudo-lager	Group III (Renaissance)
HYBRID GENOMIC COMPOSITION	50% *S. cerevisiae* 50% *S. eubayanus*	100% *S. cerevisiae*	75% *S. cerevisiae* 25% *S. eubayanus*
MELIBIOSE UTILIZATION	+	-	+
ATTENUATION RANGE	77-83%	78-84%	78-84%
FLOCCULATION	High	High	Medium
TEMPERATURE RANGE	10-15°C (50-59°F)	10-25°C (50-77°F)	10-20°C (50-68°F)
ALCOHOL TOLERANCE (ABV)	13%	14%	13%
PITCHING RATE	100-200 g/hl	50-100 g/hl	50-100 g/hl

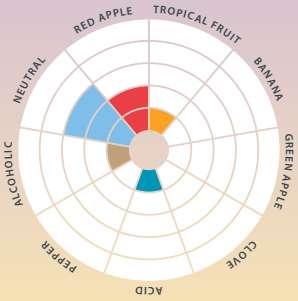
FLAVOR & AROMA



Neutral



Slightly fruity, neutral



Clean, low to medium ester, no sulfur

LalBrew®

NOVALAGER

THE FIRST MAJOR LAGER YEAST STRAIN INNOVATION IN CENTURIES.

LalBrew NovaLager™ is the first commercial example of a Group III lager strain. This novel strain has unique characteristics, including:

- Efficient fermentation and high attenuation to produce crisp, highly attenuated lagers
- Short maturation times due to the inhibition of H_2S formation and low production of diacetyl
- Unique flavor profile consisting of fruity, vibrant, and clean aromas
- A broad fermentation temperature range from 10 to 20°C (50 to 68°F)
- Lower pitch rates compared to traditional lager strains
- Bottom fermentation typical of lager strains

AB VICKERS ENZYME & PROCESS AID SOLUTIONS FOR LAGER BEERS

Many of the most successful craft and industrial breweries in the world use enzymes and process aids to improve their lager beer process. Listed below are the most popular AB Vickers enzymes and process aids for lager brewing. A full list of AB Vickers products, including nutrients, can be found at www.lallemandbrewing.com.

PRODUCT TYPE	APPLICATION	PRODUCT	BENEFITS
Enzyme	Diacetyl Reduction	**Acetolactate Decarboxylase (ALDC)**	• Reduces cold conditioning time • Prevents the formation of diacetyl
	Stabilizer	**Clarizyme**	• Prevents chill haze in beer • Enables the production of gluten-free/gluten-reduced* beer from barley malt. **depending on the legislation of each country* • Increases maturation production capacity
Process Aids	Kettle Fining	**Compac CG (carrageenan)**	• Improves colloidal stability, by removing soluble proteins • Longer filtration runs
	Beer Fining	**Protofine**	• Reduces cold storage time • Improves beer haze and colloidal stability • Vegan friendly
		Protosol	• Reduces cold storage time • Improves beer haze and colloidal stability • Natural pectin based, Vegan friendly
		Cryofine (isinglass)	• Promotes flocculation • Reduces cold storage time • Improves beer haze and stability
	Antioxidant	**Vicant**	• Prevents staling • Improves colloidal stability • Slows rate of browning
	Stabilizer	**Alphaclar S (PVPP)**	• Improves colloidal stability • Prevents haze formation • Extends beer shelf life
		Britesorb BK75 (silica hydrogel)	• Improves colloidal stability • Prevents haze formation • Extends beer shelf life