Lager Yeast and Fermentation

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Key Points of Lager Production

- Yeast Pitching
- Aeration
- Yeast growth
- Fermentation
- End of Fermentation protocols/Kräusening
- Flocculation and Yeast harvesting
- Maturation
- Flavor

•Yeast Pitching

- Amount of yeast added
  - Target pitching 1.5 million cells per degree plato(pitch 18 million cells/ ml for a 12 plato lager)
- Condition of the yeast
  - Pitch yeast that has been recently harvested, yeast that was harvested within the past week and fed, or yeast that has not been stored under fermented beer for excessive time
  - Alcohol, low pH of dense slurries, elevated temperatures (diacetyl rests) as well as hydrostatic pressure are all bad for yeast. What is good for the beer is not always good for the yeast!
  - Temperature, time and agitation are detrimental to stored yeast health
  - Deterioration is resultant from continued intra-cellular metabolism leading ultimately to autolysis

Yeast Pitching

- Underpitching
  - Slow fermentations
  - Risk microbiological integrity
  - Increased acetaldehyde, SO2, esters and increased beer pH
- Overpitching
  - Off yeasty flavors
  - Increased acetaldehyde, pyruvic acid and acetoin

Knockout

- Aerate in-line between chiller and fermenter with sterile air (not oxygen)
- At 50-53F, wort saturated with air will give 8-10 ppm dissolved oxygen
- Knockout colder than fermentation temp!
- Flotation tanks for lagers when fermented in flat bottom fermenters
  - Can’t remove trub in flat bottom fermenter
  - Can’t harvest yeast if flat bottom filled with trub

•Aeration

- Under aeration will result in
  - Slower fermentations
  - Higher acetaldehyde, SO2
  - Lower alcohols
  - Lower yeast growth
  - Lower yeast viability
  - Lower yeast yield

- Over aeration results in
  - Higher peak cell count
  - Higher peak acetoin and higher end of primary acetoin
  - Increased esters
  - Lower SO2

Old fashion aeration

Coolship at Bavarian Farm Brewery

•Yeast growth

- Lag phase
  - O_2 absorption, trace nutrient uptake, metabolic pathways primed, cell size and weight increase
  - 12-24 hours dependent on yeast condition and temperature
- Log Phase
  - Growth Phase to Final Population of 90-110 millions cells/ml common
  - Population reaches peak in 60-72 hours
  - Inadequate aeration or yeast lacking proper glycogen reserves can limit growth

pH

- 5.1 to 5.4 at end of boil
- 4.2 to 4.4 at end of fermentation
  - ≥ 4.6 bacteria active and taste affected

Open Lager Fermenter

(Kloster Brauerei Ettal, Ettal)

Open Brewpub Fermenters

Fliegerbräu, Munich

•Fermentation

- Temperature is the most important fermentation parameter as far as flavor
- Higher temperatures result in higher esters and fusel alcohols
- 1:1 height to width ratio produces best beer
- Vertical liquid height not to exceed 35’
- Hydrostatic pressure and stripping affects of CO_2 evolution important
- Cone cooling important for sedimenting yeast

Fermentation

- Primary Fermentation, 45-58°F common for American Lagers
- Secondary Fermentation generally cooler, 43-53°F, typically for American lagers
- Fill fermenters on a continuous basis or else less than 8 hours if possible
- Trub contains nutrients, lipids, solids and removal from yeast/wort can affect flavor
  - Zinc in trub can affect rate of fermentation, general yeast health and also flocculation
  - Lipids in trub can supplement oxygen requirements but can lead to staling characteristics later
  - Solids can provide nucleation sites for CO_2 evolution; high levels of CO_2 may inhibit yeast growth and fermentation

Open fermenters in Bavaria

Closed fermentation at Ayinger

•End of Fermentation

- Timing of cooldown at end of fermentation affects secondary metebolites such as diacetyl
- Initial cooldown ramp of 4-8°F over 24 hours to drop yeast out of solution is common
- Cooldown ramp also affects SO_2 content of beer
- Initial cooldown may begin with residual extract in beer to be used for natural carbonation

Kräusening

- Freshly yeasted wort(4 hours minimum) is sometimes added at a rate of 10-20% of total volume
- CO_2 is not collected on newly kräusened beer for the first 24-72 hours
- Kräusening overcomes the problem of yeast going dormant during the lagering phase of fermentation
- Kräusening also helps clean up the flavor of the beer by reducing levels of diacetyl, acetaldehyde, and dries out the beer

•Flocculation

- A single strain will vary widely on ability to flocculate when presented with various environmental conditions
- The onset of flocculation is encouraged by:
  - Absence of sugars
  - Lower pH
  - Presence of ethanol
  - Presence of divalent ions (Zn, Mg, Ca)
  - All effects are additive

Yeast harvesting

- Most lager yeast should be harvested and repitched no more than 6 generations
- Lager yeast is prone to respiratory deficient mutations (petites) which produce excessive amounts of diacetyl
- Serial repitching can select for older/younger cells which have different flocculation characteristics
- Flocculation potential increases with cell age; older cells have more bud scars
- Cooling the yeast too fast after primary fermentation can shock the yeast out of suspension; some yeast in suspension is necessary for lager beer maturation

Yeast storage

- Store yeast at 32-36°F but avoid freezing
- Use light or intermittent agitation necessary for cooling, degassing CO_2 and homogenizing
- If stored in glycol jacketed brink, do not operate glycol temperature less than 28°F
- Higher temperatures and longer storage produce slower fermentations with lower peak cell counts
- Repitching yeast from all but the most adverse storage conditions showed a return to normal fermentations

Oops!

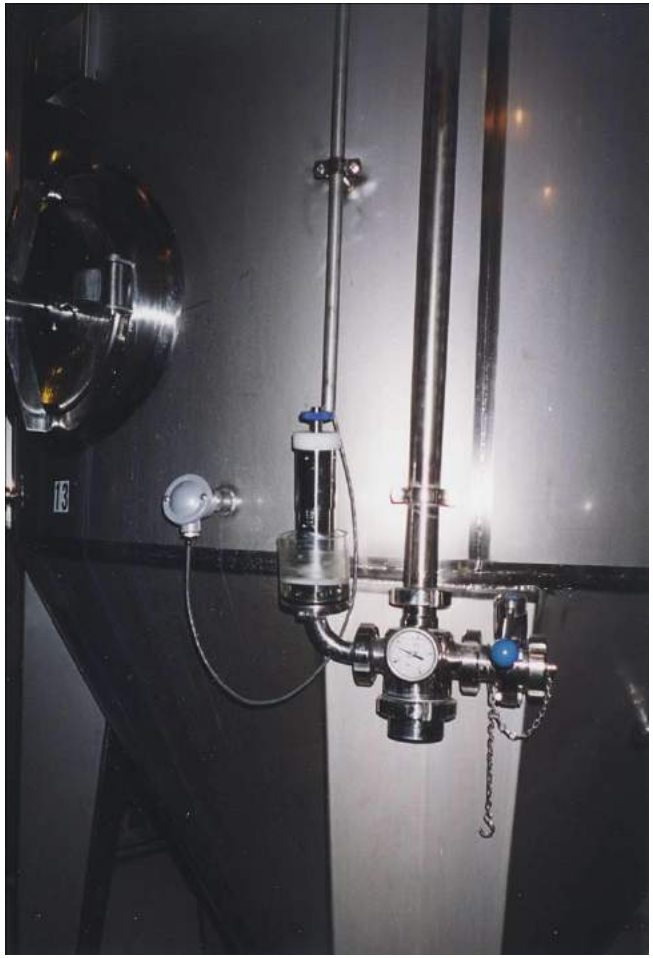
•Maturation

- After initial cool down to drop harvesting yeast out of suspension, begin drop to lagering temps
- Ideally drop to lagering temperature by 1˚C/day to a final temp of 0-2˚C for German Lagers, higher temperatures for American style lagers
- Most German brewers collect CO_2 from the end of primary fermentation throughout the lagering process with a Spundapparat or similar device
- Flavor development occurs (diacetyl, acetoin, aldehydes, sulphur compounds reduction)
- Esters and ethanol increase slightly

Lager Keller

Spundapparat

pressure-relief valve for carbonation



Beer from the Lager Tank

Taste the freshness and SO_2

Paulaner Bräuhaus, Munich

Cold aged doppelbock from Kloster Weltenburg

•Flavor

Factors contributing to increased SO_2

Dr. Greg Casey, Coors Brewing

- Lager yeast strain produces more $S0_2$ than ale
- Spunding and kraeusen (trapped CO_2)
- Sulfates in water
- Cold temperature (Miller – beer fermented at 10˚C 2x more SO_2 than at 15˚C)
- Suntory of Japan noted more SO_2 with all malt beers than with adjunct beers

German Lagers may have higher levels of SO_2 (sulfur dioxide) than American lagers

- SO_2 should not to be confused with:
  - DMS – inadequate boil (should never be found in German lager)
  - H_2S – stressed yeast / unwanted microbes
- Lager yeast naturally produce more SO_2 than ale
  - German brewing techniques produce/trap more SO_2
  - Cold fermentation, cold lagering
  - Natural carbonation (forced carbonation scrubs SO_2)

Factors contributing to decreased SO_2

- Pasteurization
- Higher beer storage temps
- Increased tank venting
- CO_2 release purges SO_2 from beer
- Fast fermentations
- Non-pressurized fermentation/conditioning

Bottom Fermentation (lager) Overview

- Pitch 15 to 30MM cells/ml
- Knockout colder than fermentation temperature @ 6 to 8˚C
  - Oxygen solubility ↑
  - Protection against invading microbes
  - Reduces fruity/spicy higher alcohols and esters
- Free rise to 9 to 10˚C, achieve about 80 - 90% of attenuation limit in 1 week
- Drop to lagering temperature (0 to 2˚C) by 1˚C/day (DON"T CRASH!!!!!)
- Condition for 3 or more weeks (diacetyl rest sometimes used by larger brewers up to 20^{o}C)
- Tank is bunged and remaining extract (1 – 2% remaining fermentable extract) or added kraeusen (10%) carbonates beer

Monastery Weltenburg – Munich Dunkel
2008 World Beer Cup Gold Medal

Malt:	75% Munich, 20% pale, 5% specialty (caramel and roasted)
Water: Grist	Ratio: 3 to 1
Mash (2 decoctions)	Mash in @ 52°C, rest 10 min
	Pull 1st decoction (30%) & boil 20 min
	Rest @ 63°C, rest 30 min
	Pull decoction & boil 20 min
	Mash off @ 74°C
Lautering	Vorlauf – 5 to 10 min
	First wort runs off in 1:15 hr
	3 sparge water additions @76°C
	Total lautering time = 2.5 to 3.0 hr
Boil	50 min @ 103°C (external calandria)
Hops	3 additions: 1st @ boil start; 2nd after 25 min; 3rd at end
	IBU - ??
	(Probably Hallertau/Hallertau and/or Hallertau/Perle)
Whirlpool	20 min stand
Knockout	12.5°P @ 6°C w/ 2 stage counter flow wort chiller
Aeration	6 mg of O_2 and pitch proprietary yeast @ 30MM cells/ml
Flotation	2 hours
Primary	7 days @ 9°C in flat-bottom enclosed fermenter – fully attenuated
Conditioning	3 to 4 weeks @1˚C w/kraeusen for natural carbonation
Filtration	DE

Export Hell
(small Bavarian brewer)

OG	12.3˚P
BU	na
H_2O treatment	sour wort - 1% of knockout volume added at mash in, 0.5% added in kettle
Salts	$CaCl_2$
Malt	96% pale barley, 2% carahell, 2% caradunkel
Water: Grist	na
Mashing	(1 decoction)

Temperature (˚C)	Rest (min)	Comment
58	15	Mash in
64	20	Pull decoction to raise mash to next rest; boil 10 min
72	25	After 10 min. pull 1st decoction
75	--	Transfer to lauter tun

Lautering		2:20 hr total; 1:00 first runnings, 1:20 for 2 sparge additions
Boil		1:30 hr
Hops	1st	30% Hallertau Perle 10 min after boil start
	2nd	30% Hallertau Perle 30 min after boil start
	3rd	20% Tettnang 60 min after boil start
	4th	20% at knockout
Ferment		Cool to 7˚C in 65 min.

Schoenramer Pils

Brauerei Schoenram, Schoenram, Bavaria

- Soft water, low alkalinity, chloride and sulfate ions enhances body and aroma respectively
- Very pale barley variety with a lot of enzyme activity (we use the variety Barke, the palest available)
- Intense mash, single-decoction best as it boosts attenuation. Rests vary according to year, but a long time around 65°C is necessary
- High attenuation (>87% apparent) enhances hop character (dryness) and at the same time, through the higher level of alcohol, adds a sweetness to balance out the bitterness
- I am a proponent of aroma hop varieties and use only aroma varieties for my Pils (as for all my beers), even for the bittering - 4 different varieties given 5 times, more than 50% as late hopping, all are Bavarian hop varieties from the Hallertau and Spalt (the varieties and combination a secret I'm not at liberty to give away)
- Enough evaporation to drive out DMS (> 5.5%)
- Acidification of mash and wort to adjust pH (lactic acid derived from the malt and propagated to around 1.5%)
- Hot trub separation with the whirlpool, cold trub separation with flotation tank
- Fermentation in open vessels beginning around 7°C, max. temperature 9°C, pitching rate 18 million cells per ml (about 1 liter of thick yeast per hl)
- Ferment close to final attenuation, cool to 3°C over 2 days (total fermentation time with cooling around 8 days) add 8% kraeusen beer when transferring to lagering
- We skim our fermentation head almost daily
- Hold in tank at 3°C for 2 weeks until vigorous secondary fermentation begins to calm down, gradually cool to below 0°C (around minus one) over two weeks
- Last two weeks below freezing, total lagering 6 weeks, 5 weeks is also OK, but not less
- Ensure minimal oxygen take-up at bottling

Beer Warmer

Spezial Braeuhaus, Bamberg

Forschungbrauerei

Paulaner Brewpub

Prost!

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