Acidification in the brewhouse

Why acidify?

- Definitely not needed on darker beers
- Not needed at all, but is another optimization
- Better enzyme activity in mash
- Better PI
- Better trub
- Better flavor stability
- better ferment/diacetyl reduction

Areas to acidify

- Mash
  - Can also use acidulated malt
- Sparge water
- Kettle
  - Ideally to 5.0-5.2 pH (cold)

acids

- Lactic acid (biologische Milchsaeure)
  - Developed because of Reinheitsgebot
- Industrial acids
  - Food grade sulfuric or phosphoric common

Biologic lactic acid

- Advantages vs. industrial acids
  - Natural process; probiotic
  - Better flavor
- Drawbacks vs. industrial acids
  - Investment
  - Qualtity control of sour wort
  - Need steady brewing schedule
  - Takes practice

Lactic acid propagation

- Many kinds of lactobacillus can be used, but most common is delbrueckii (homofermentative)
- Best to source a pure starter culture
- Feed the reactor with 50/50, 1st wort/water
- Propagate at 45-48C
- In 24hrs close to 1%. In 48 hrs, 2% possible
- Dose and refill to <0.5%

Bio-reactor set up

(from L. Narziss – Die Technologie der Wuerzebereitung)

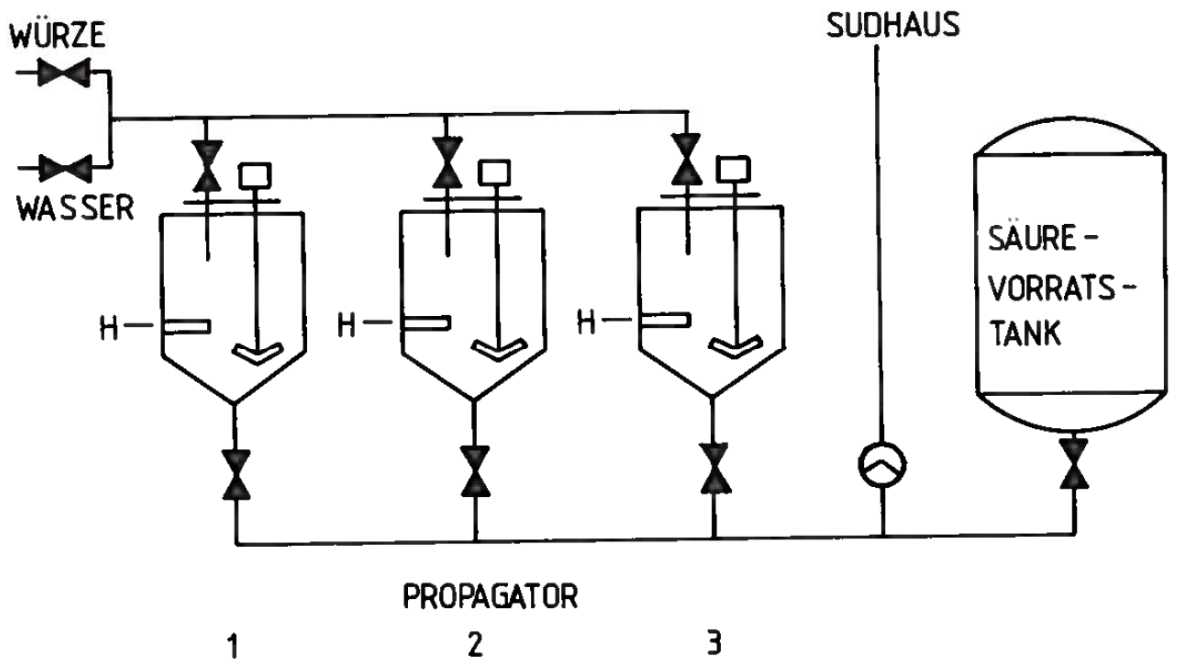

Abb. 10 Anlage zur biologischen Säuerung (H: thermostatische gesteuerte Heizstäbe)

Berliner Weisse

- Notes taken from the VLB publication “Die Berliner Weisse”

Classic technology (post 1930)

- Barley malt:Wheat malt = 1:3 – 1:4
- OE 7 – 8 P
- Hopping rate is 1kg/100kg malt. The spent hops were then boiled in water and then used to infuse into mash to raise mash temp. Also, the residual hop cones improved lautering.
- The wort was not boiled. Attention Sarcina (cocci bacteria). Therefore heat to 85-88C before transfer to coolship.
- Boiled wort restricts the bacteria and beer is less sour.
- Any ale yeast will do
- Fermentation temps: high is 17-20C, low is 14-18C
- Rods:yeast = 1:4 (warm) and 1:6 (cold)
- Wort is pitched with an already mixed culture of yeast and bacteria.
- Warm temp makes more acid.
- Ferment to completion, then bottle condition with 12-15% krausen.
- 0.5-0.55% CO2
- Bottle condition for 2-3 weeks at 12-16C.
- Brewed in winter and served in summer.
- During bottle conditioning, ***brettanomyces bruxellensis*** was active.
- Trials without brett were unsatisfactory in regards to matching the classic Weisse aroma.
- 1956 method: Ferment 80% with yeast/lacto mix, ferment 20% unhopped with lacto (Brevis), then combine, age and sterile filter (an attempt to create consistent process).
- Creating a process that results in consistent beer flavor was the challenge for a long time.
- Another method is mash in at 50C, add L. delbrueckii (or natural?), let sit to sour, continue mash program, then run off and ferment. Due to the pH<5.0, the alpha amylase may not achieve iodine normality of the mash.

Classic Fermentation

Time	Plato	Yeast conc. ($x 10^6$)	Bacteria conc. ($x10^6$)	Temp. (C)	Ratio of yeast:rods	% acid
pitching	11	10	2.6	17.5	4:1	0.2
18 hrs	10	56	8	19	7:1	0.3
40 hrs	5.5	76	22	22	3.5:1	1.4
64 hrs	3.0	12 (most is cropped)	7.2	23	1.7:1	1.8
5 days		0.5 (est.)	0.4			2.0

After 3 days, the krausen cap has been on the beer for 1 day. The krausen contains yeast:rods = 7.5:1.

After 6 days, the krausen cap has been on the beer for 4 days. The krausen contains yeast:rods = 3.7:1.

The settled yeast contains yeast:rods = 3.3:1

Problem fermentations

Problem	Probable cause	Remedy
Dead fermentation	Termobacteria infection at the coolship	Keep wort >60 C until wort cooling
Boiling fermentation	Over-modified malt	Mash in at higher temp.
Red hue in beer	Oxidation of the unboiled wort at the coolship	Minimize hot wort time in coolship and quick start to fermentation
Slimy beer	Pediococcus infection	Wort boiling, short lag time, quick growth of lacto

1938 Descriptor of Berliner Weisse

- Light color, sour and mild, dry, high carbonation and high, stable foam.
- OE: 7-8 P
- ADF: >75%
- CO2: >0.6%, 0.8% in bottle is best
- IBU: no spec, but low
- Color: 9 – 15 EBC
- Label color: dark green

Newer specifications (1990s)

Measurement	units	Normal range
Original extract	P	7.1-7.5
Apparent extract	P	0.6-1.8
Real extract	P	2.0-2.8
Alcohol	Abv%	2.9-3.6
ADF	%	80-90
pH		3.3-3.6
Color	EBC	4.5-6
Bitterness	IBU	3.0-4.4
Viscosity	mPa*s	1.3-1.4
Foam (R&C)	s	90-120
CO_2	%	0.6-0.8
Anthocyogenes	ppm	9-23
Total polyphenols	ppm	44-93
Total protein	ppm	418-550
Coaguable protein	ppm	17-22
$MgSO_4$ prec. protein	ppm	126-288
Higher alcohols	ppm	74-189
Acetic acid	ppm	66-731
D/L-Lactic acid	ppm	1110-4620
Citric acid	ppm	0-87
Succinic acid	ppm	54-185
Succinic acid diethyl ester	ppm	0-4.1
Ethyl acetate	ppm	6.0-87
Ethyl lactate	ppm	8.1-346

More characteristics

- Brett is absolutely required to achieve the aroma of a classic Weisse.
- Levels of fermentation by-products are dependent on the presence or not of Brett.
- Lactic acid levels of >2% can be achieved.
- Modern methods achieve 1 – 1.5% acid, clean consistent sourness, but miss some aroma due to lack of Nachgaerung, or bottle conditioning.
- The author keeps coming back to the fact that modern ‘big brewery’ methods can miss the classic aroma.

Microflora

- Originally fermented in wood, which over time developed house characters
- Size of weizen yeast is 5-10micrometers x 3-8 micrometers, oval.
- Size of lactobacillus rods are 3-6, up to 15 micrometers x 1 micrometer.
- Lactobacillus, mainly *brevis*, is responsible for the 1.5-2% lactic acid, the volatile organic acids (acetic acid, propionic acid) and pH of 3.2 – 3.6.
- Brevis is heterofermentative, creating lactic acid and small amounts of alcohol and CO2.
- Brevis will ferment Fructose, Glucose, Maltose, Pentose and Melibiose.
- Inoculation should be at least 1:1, but can be up to 5:1 (yeast:bacteria). This is where consistency is difficult batch to batch.
- Other lacto strains that are often present are: buchneri, lindneri, casei, coryniformis, plantarum.
- A mix of the strains is required for the classic aroma.

Microflora (continued)

- Beer must be very lightly hopped to not inhibit growth of the bacteria.
- 20 – 24C is optimal to get high acidity levels. Reaction is slower, but end result is higher in beer.
- At 8% ethanol, bacteria growth is inhibited.
- L. delbrueckii is homofermentative.
- Research in early 1900's identified lacto cultures and called them L. pastorianus and L. berolinensis, later thought to be mainly L. brevis.
- Brettanomyces cells are polymorphic. Can be oval, lemon shaped or sausage shaped.
- Brett was originally isolated out of lambic beer and grape must.
- Brett is called a "Nachgaerhefe" (post ferment yeast). Added after fermentation, it digests the residual sugars into acids and alcohols which create esters, resulting in the typical brett aroma. Brett contributed (es?)to the classic English porter aroma.

Microflora (continued)

- Brett can work up to 15% abv, but ferments slowly.
- Brett was not recognized as a part of Berliner Weisse until the latter half of the 1900s.
- Brett creates large levels of lactic acid ethyl ester and acetic acid ethyl ester: ethyl lactate to avg. 150 mg/l (lager has almost none) and ethyl acetate to avg. 40 mg/l (lager has well below 20 mg/l). Flavor thresholds are 50ppm for ethyl lactate and 17ppm for ethyl acetate, so the Brett obviously contributes a unique component to the Weisse that would not be present without it.
- Brettanomyces bruxellensis ferments glucose, maltose, saccharose, melicitose and trehalose, but not the sugars galactose, raffinose, lactose or cellobiose. Fermentative potential for other smaller chain dextrins has not been confirmed as yet.

Microflora (continued)

- After longer aging of many months or even years, a further saccharification happens. This could be due to other wild yeasts or it could be that the acids are hydrolyzing some dextrins into fermentable sugars.
- To achieve desired aroma levels, the brett concentration after primary fermentation need to be at least 5 x 10^6 cells/ml (5 million cells/ml).
- Brett ferments well at 15 C, so seems to be a suitable post-fermentation temp.
- Being a slow fermenter, some aging time is required for the aroma to develop.

Modern methods

- Now not only brewed in dedicated Berliner Weisse breweries, it is being brewed in breweries that mainly produce lager beer. Therefore, the use of pure cultures is required.
- The cellars should be kept separate as well as the CIP systems.
- Comparison of 3 different breweries. Brauerei I and II use a more classic method with open fermentation. Brauerei III uses a modern method with cylindro-conical tanks:

Comparison of Modern Methods

Attribute	Brauerei I	Brauerei II	Brauerei III
Malt mixture	Barley and wheat	Barley 100%	Barley 100%
Mash profile	infusion	Single decoction	Infusion
Hopping	Whole hops, mash hops	Hop extract	50% of wort is boiled with hops, cooled and fermented with yeast 50% of wort is not boiled and not hopped and inoculated with lactobacillus
Wort boiling & cooling	No boil. Lautered wort is cooled into fermentor	5 minute boil	See above cell
Microorganisms	Mix of yeast and lactobacillus (multiple strains) Brettanomyces is included.	Same as Br. I	See above.
Pitching	0.1 liters yeast/hl at 18C	0.5 liters yeast/hl at 20C	Yeast half at 20C. Lactic half at 45-47C.
Primary fermentation	18C in open vats	Without cooling for 2-4 days, 20-25C	Yeast half at 20-22C. Lactic half at 45-47C. After 2 days, pH=3.0, AE=6-6.5P
Aging	1st step in lager tank for acidification, 2nd step with krausen into the bottle for bottle fermentation.	Same as Br. I	Depending on acid level, mix both halves 50/50 or 60/40. One week aging at 15C under pressure.
Bottle conditioning	4-6 weeks at 15-20C	4-6 weeks at 20C	None
CO2	0.6-0.7%		Beer is very coarsely filtered and carbonated
O.E (P)	7.2-8.1	7.5-7.7	7.4
Alcohol (w/w)	2.8-3.3	2.6-2.8	2.3
R.E (P)	1.2-1.6	2-2.2	2.8
pH	3.4-3.6	3.5-3.8	3.3
Carbohydrates (g/100ml)	.23-.41	.46-.5	1.56
Acetic acid (g/l)	.21-.58	.43-.65	.09
D/L-Lactic acid (g/l)	1.3-2.4	1.0-1.7	2.1
IBU	4.7-6.5	5-9	3.4

Suggested methods to brew Berliner Weisse in a modern large brewery

- Barley:Wheat malt = 50:50
- 9700 kg malt to make 600 hl cold wort
- OE of wort 12.5P
- 1865g alpha/hl wort, added to kettle at beginning of lautering. Goal is 6 or 7 IBU in beer.
- Infusion mash profile temps (C): 52-64-72-78.
- No wort boiling. At kettle full, heat to 96C and rest for 20 minutes.
- Cast to whirlpool and hold 20 minute rest.
- Cool wort to 20-21C and aerate at 8-10mg/l O_2.
- Pitch with old Weisse and harvested mix-culture. In the example, the tank's contents would be 1200hl wort, 200hl old Weisse, 4hl harvested mix-culture. 11.8P, $6x10^6$ yeast cells/ml, 21C, 1 bar pressure. The beer is mixed by circulating with a pump.

Suggested methods to brew Berliner Weisse in a modern large brewery (continued)

- Fermentation: 3-4P per day, temp up to 30C. At end: AE 0.8, pH<4.0, lactic acid>1%, yeast concentration at $30x10^6$.
- When AE<1P, dilute down to desired OE. In this example, about 800 hl water is needed at <3C. The water must be deaerated (could be boiled and cooled), otherwise the extra oxygen could lead to very high acetic acid concentrations.
- After dilution: 2200hl, OE 7.5P, AE<0.8P, IBU 6-7, lactic acid <4g/l, temp 15-20C, pressure 1-2 bar.
- Circulate to mix.
- Stop mixing after lactic acid >4g/l and AE<0.6P.
- Harvest yeast after 48 hrs.
- Reduce to <10C to settle out more yeast.
- No bottle conditioning. Carbonation can be touched up when cold in tank.

Optimized production with pure bacterial cultures

- The goal of modern Weisse brewing is to replicate the classic flavor in a consistent manner. Achieving a consistent and shelf stable acidity seems to be the variable most difficult to control.
- The following suggestions are made:
- Unhopped, unboiled wort is inoculated with a lactobacillus strain and fermented at 20-30 C. In the example, L. casei was used (homofermentative).
- Once the desired level of acidity is achieved, that is fixed by thermally inactivating the bacteria.
- The sour wort can now be cut with regular hopped, fermenting wort or simply fermented as is with yeast.
- Fermentation goes until about 1P.
- After primary fermentation, the beer racks into a tank and Brettanomyces bruxellensis is added.
- The brett fermentation happens at about 15C and a brett cell concentration of $5x10^6$ cells/ml.
- The effect of the wheat malt portion was found to be insignificant to the final flavor. It was determined that brewing with 100% barley malt was acceptable.
- Bottle conditioning is not required.

Influencing the acidity of the beer

Increases acidity	Decreases acidity
No wort boiling (heat to 85-88C)	Boiling the wort
Acidifying the kettle full wort	No acidification of wort
Pitching temperature > 20C	Pitching temperature 15 – 18C
Increasing pitching quantity by adding old Weisse	No addition of old Weisse
Dilution after fermentation	Dilution before fermentation
Delayed yeast harvest	Prompt yeast harvest
Warm-aging temperature > 20C	Warm-aging temperature 10-15C
Cold aging temperature >5C	Cold aging temperature <1C
Yeast storage >10C	Brief (2 days) yeast storage at 8-10C
Yeast:Bacteria = 1-4:1	Yeast:Bacteria = 4-8:1

Effects of lactic fermentation

- pH from wort to beer of avg. 5.5 to 3.2-3.8
- improved color- and haze-stability
- improved flavor stability
- obvious unique flavor and aroma contributions
- creates lactic acid which has health positive aspects, especially the L+ configuration

Other notes

- aging of Berliner Weisse bottles can result in cherry aromas due to oxidation, which is found to be positive.
- A future development may be the use of specifically probiotic lactic acid strains.

Experience of a former Berliner Weisse brewery director (1976)

- Malt bill was 50/50 wheat/barley
- OE was 7.5P
- Fermentation at 15C in open vats with a mixed culture (various yeasts and bacteriae)
- “yeast” was scooped off the top and added directly to the next brews.
- After months of aging, beer was mixed with krausen and filled into bottles for bottle conditioning. CO_2 of 0.6 – 0.8% was the target.
- ADF was over 100%. This made Weisse a good beer for diabetics.
- With brettanomyces, it was difficult to know exactly how far bottle conditioning was going to go.
- Much easier to brew in stainless steel and ferment out completely.
- Adding aged Weisse back to fresh wort is positive in that it lowers the pH of the wort and inhibits wort bacteria in case of a slow start to the yeast or lactobacillus activity. It also gets some active brettanomyces into the wort early on.

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