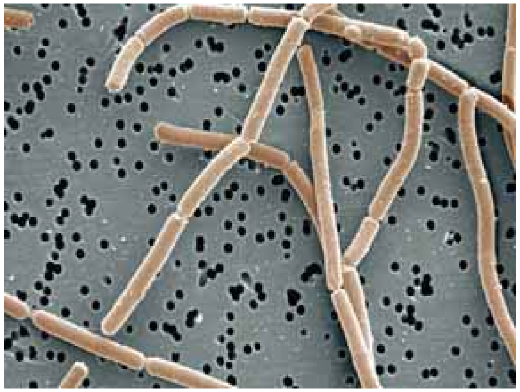
Pickled Beer: Concepts of Sour Ale

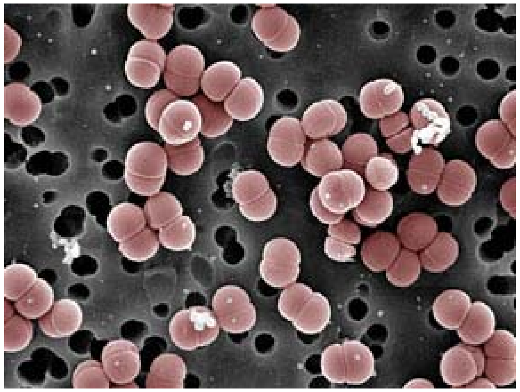
Raj B Apte

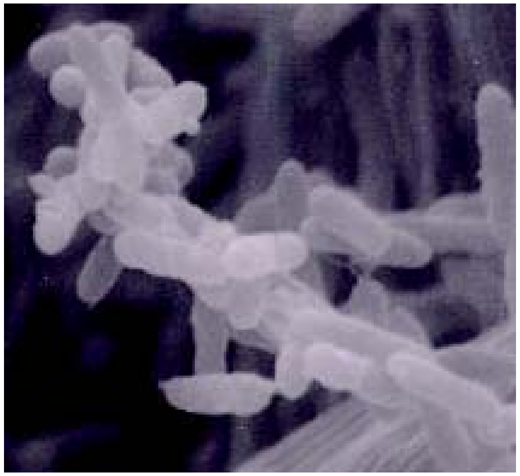
Matadero Creek Brewery

- What is sour ale: lambic, flemish red, oud bruin, berliner weiss, gose, jopenbier ....
- Cast of characters—lotsa Latin
- Fermentation: balancing food and environment
- Flemish sour ale
  - Historical basis
  - Flavor palette
  - Microbial machinery can make anything
  - Tandem fermentation: acetic acid, alcohol, lactic acid, phenols
- Procedures
  - Total acidity
  - Anti-oxidants and hop polyphenols
  - Sour mashing
  - Wood
  - Turbid mashing
- Summary of sour ale brewing

Cast of characters





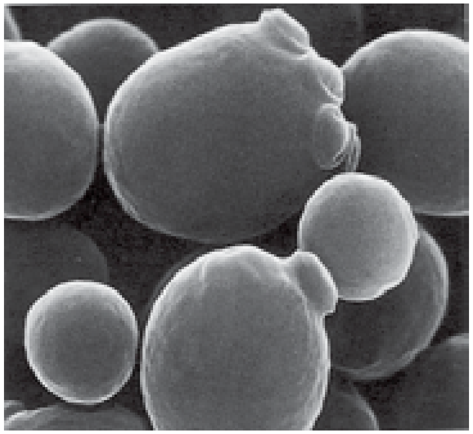


Lactobacillus
- basis of yoghurt, cheese
- lactic acid
- salt resistant; hop sensitive?

Pediococcus
- anaerobic
- lactic acid
- hop resistant
- secrete amylase?

Acetobacter
- aerobic
- pellicle forming
- inhibited by salt

Enteric bacteria
- low alcohol tolerance
- low acidity tolerance
- produce mixed acids



Saccharomyces
- sugar fungus
- aerobic or anaerobic
- produces alcohol
- bakers, brewers, vintners; hundreds of strains

Brettanomyces
- british fungus; british flavor
- aerobic or anaerobic
- Bordeaux v. Davis
- produces alcohol or acetic acid
- several species; many strains

(all photos stolen from websites—please let me know if you want attribution)

Pickling

- Sauerkraut & Lactic Cucumbers
  - wild Lactobacillus
  - 1.5% brine, similar to animal fluids
  - anaerobic
  - produce 0.1-2% lactic acid
- Vinegar and Brine
  - inoculated Acetobacter in wine
  - salt toxic to Acetobacter; brined only after acetic fermentation is done.
  - produce 5-15% acetic acid
  - aerobic
  - re-use
  - Shao Xing cooking wine
- Pediococcus
  - sausage making
  - pickled cucumbers
  - silage
  - cheese

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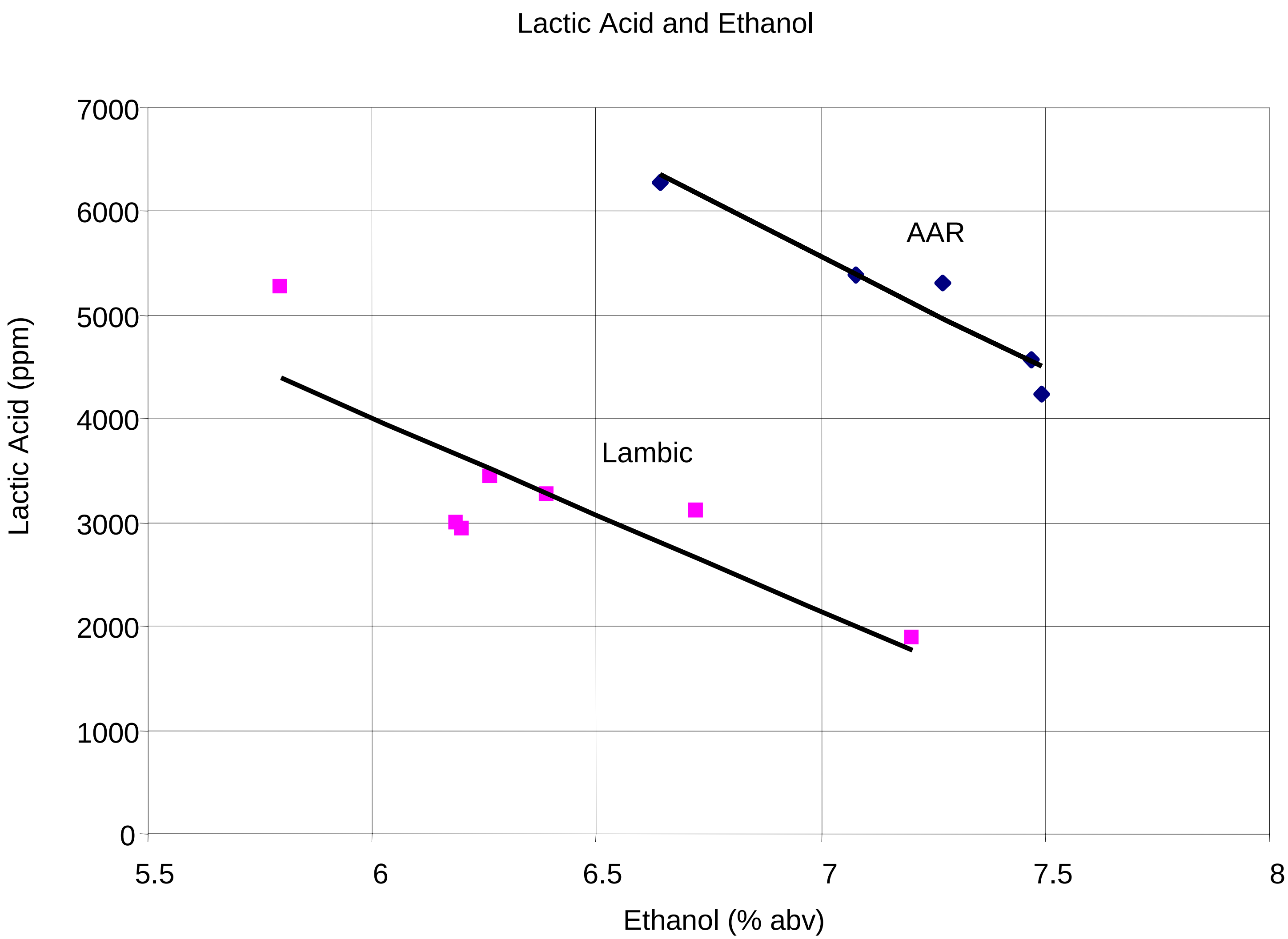
???

General Fermentation

	salt	Alcohol tolerance	Lactic acid	Acetic acid	starch	time	oxygen	temp, F
Saccharomyces	-	20%, P	pH 4.5	0.5%	-	2	+	40-95
Brettanomyces	-	15%, P		P		100	+	40-95
Lactobacillus	8%	8%	1% P	-		4		60-150
Pediococcus			2% P, pH 3.4		+	100	--	
Acetobacter	-	6-18%		8% P		30	++	70-110
Enterobacteriaceae		2%, P	pH 4.4, P	0.5%, P		2	+	
molds		-	-	--		5	++	<100

P produces
-- toxic
++ required
-, + minor effect

Ethanol toxicity in lactic bacteria



Historical context: everything was sour

- Beer 1500-1900
  - Fresh ale: cheap, common
  - Aged beer: very expensive, 2 years
    - 5% abv sour ale. Today: Flemish sour ale
    - 10% abv stock ale. Today: Barleywine, Imperial Stout
  - Porter: a blending technique.
- Flemish sour ale
  - Dextrinous wort
  - Aged hops: anti-bacteria and anti-oxidant
  - “Spontaneous” or collateral inoculation
  - Wood: the role of oxygen
  - Time
- Tandem Fermentation
  - Saccharomyces: alcohol
  - Lactobacillus: lactic acid
  - Pediococcus & Brettanomyces: lactic & acetic acid, funk
  - Acetobacter: rising oxygen levels

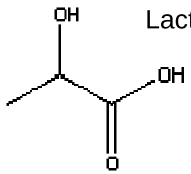
	Gueuze	Unblended AAR
Apparent Extract, Plato	0-3.9	1.2-2.5
Ethanol, v%	4.6-5.7	6.6-7.5
pH	3.3-3.5	3.2-3.3
Acetic Acid, ppm	600-1200	1500-2500
Lactic Acid, ppm	1900-5300	4200-5400
Ethyl Acetate, ppm	60-170	90-130
Ethyl Lactate, ppm	360-480	220-290

Martens

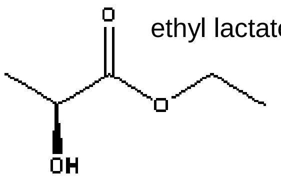
Landscape of sour ales

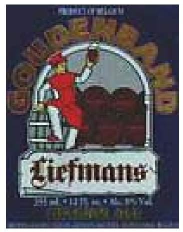
Lactobacillus
Pediococcus

Lactic acid



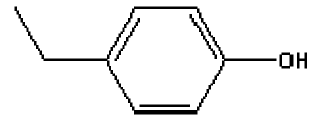
ethyl lactate



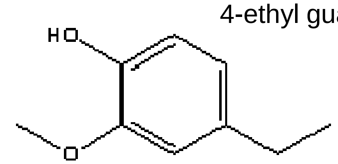


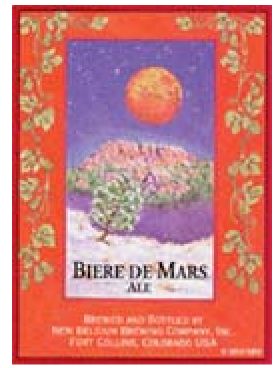
Brettanomyces

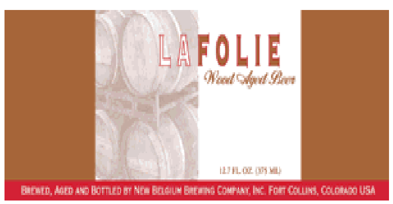
4-ethyl phenol



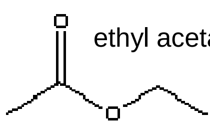
4-ethyl guaiacol



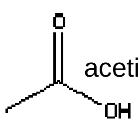




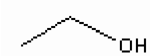
ethyl acetate



acetic acid



Ethanol



Acetobacter
Enterobacteriaceae

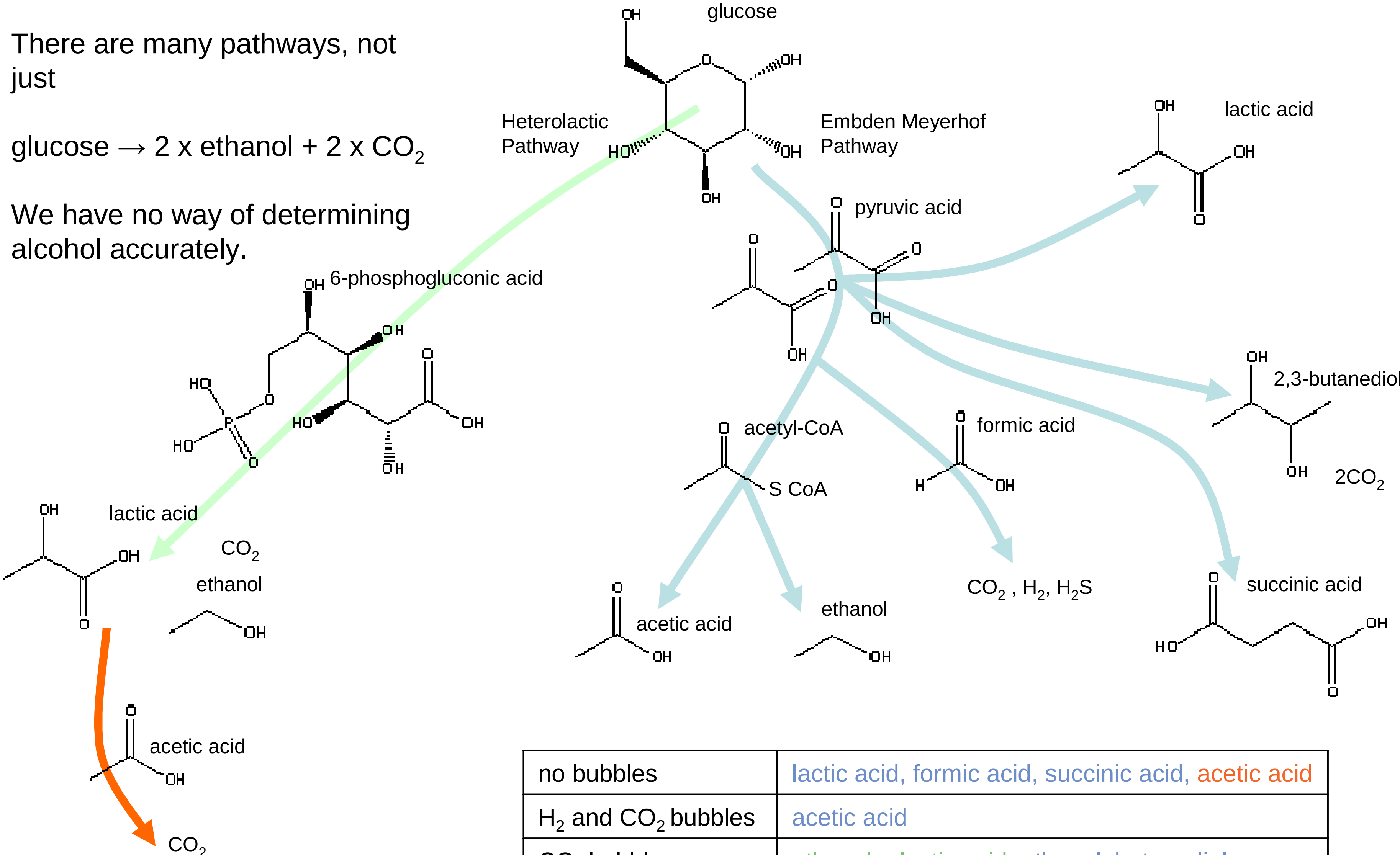
Saccharomyces

We are not in Kansas anymore

There are many pathways, not just

glucose → 2 x ethanol + 2 x CO_2

We have no way of determining alcohol accurately.



no bubbles	lactic acid, formic acid, succinic acid, acetic acid
H_2 and CO_2 bubbles	acetic acid
CO_2 bubbles	ethanol + lactic acid, ethanol, butanediol

Tandem Fermentation

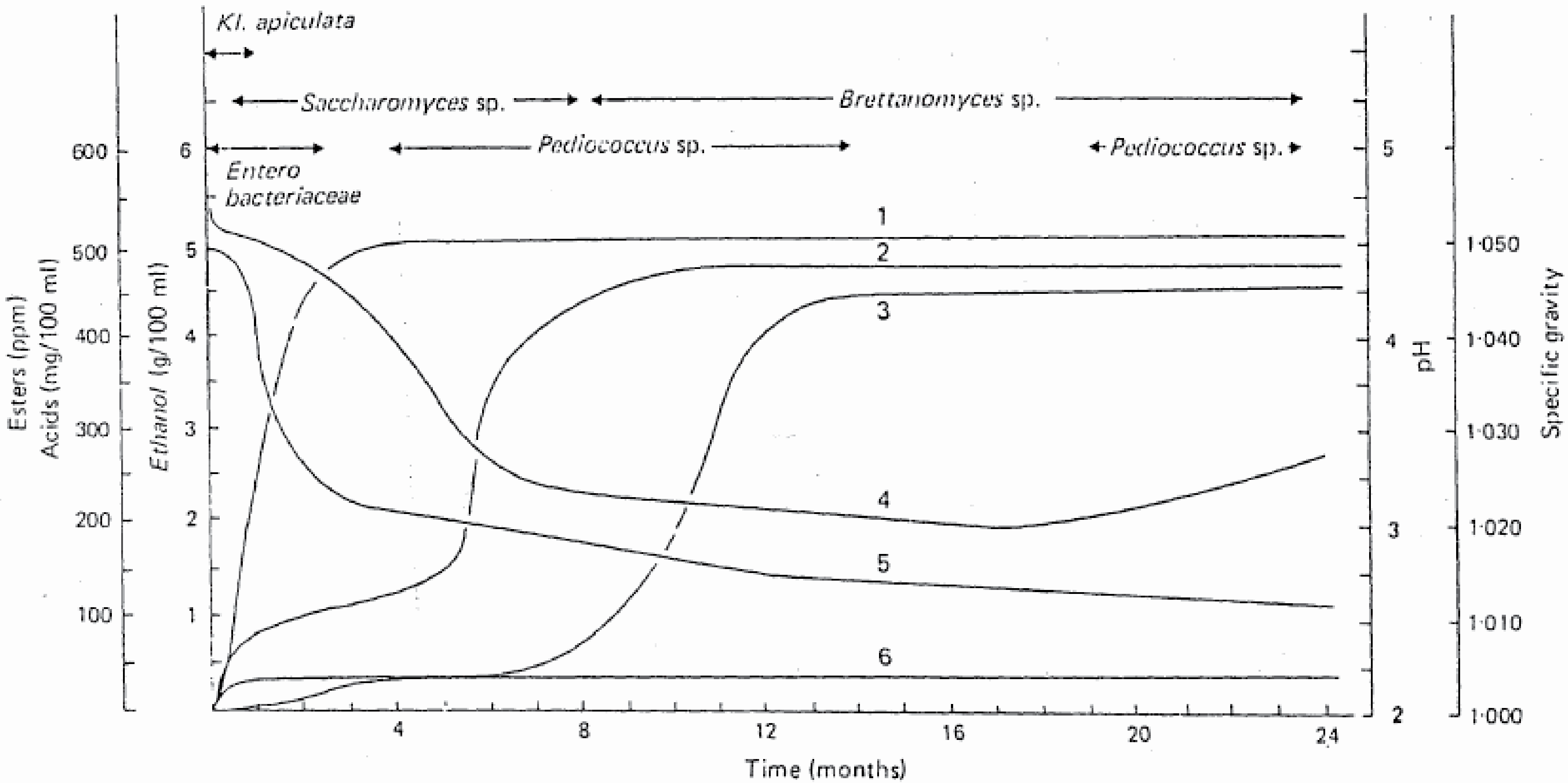
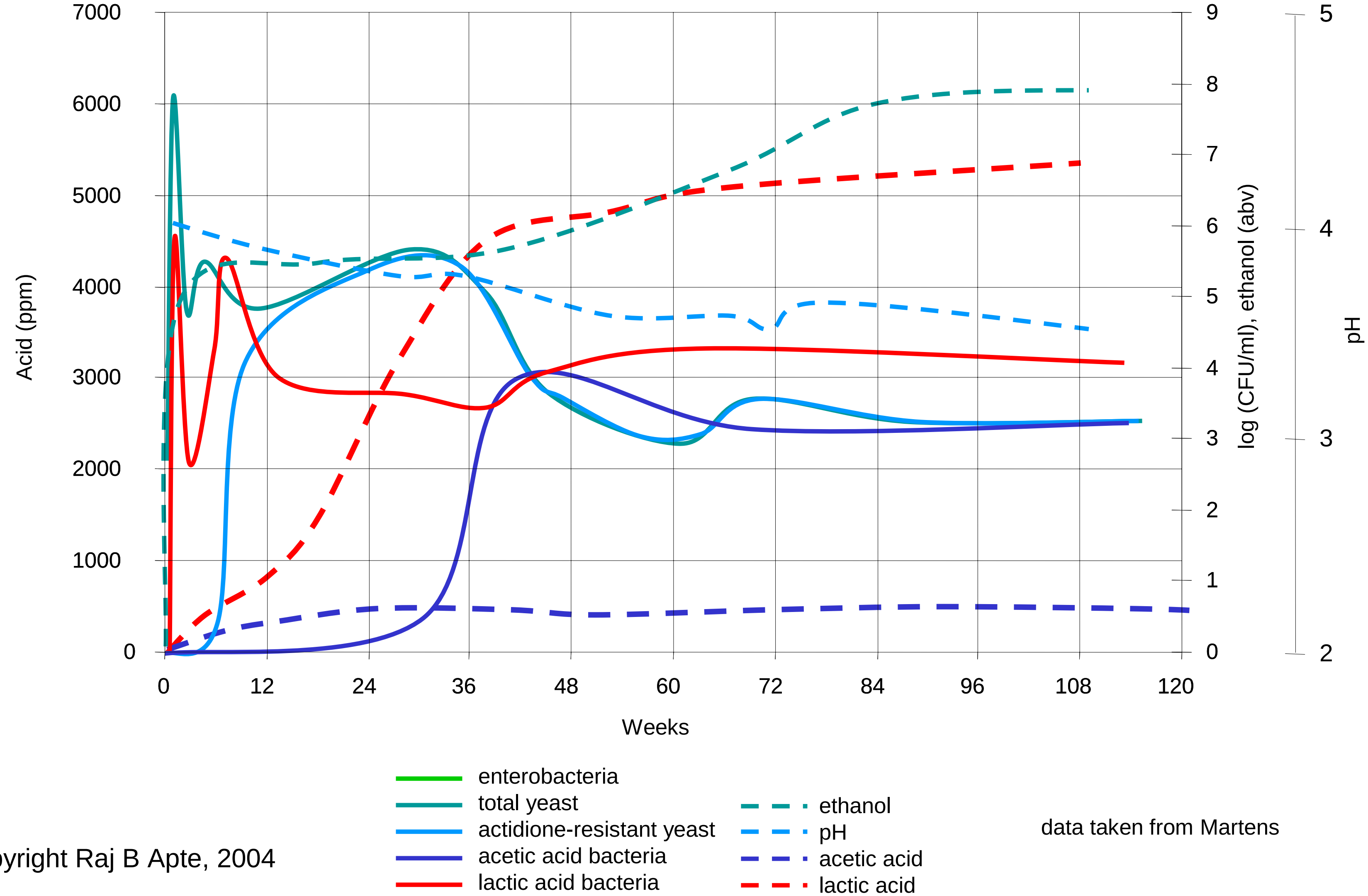


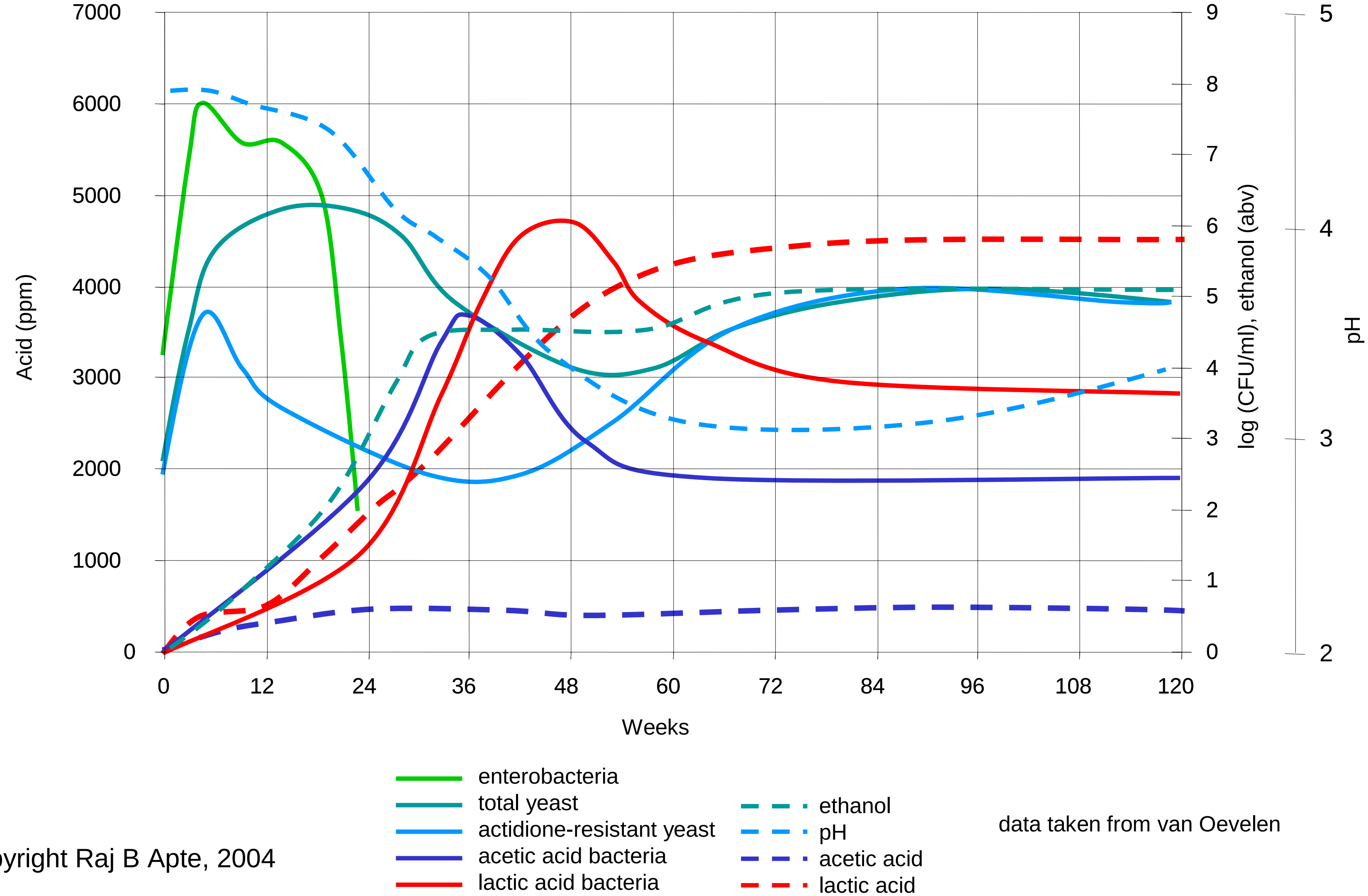
Figure 3. Evolution of some important parameters of spontaneous lambic fermentation: 1 = ethanol; 2 = lactic acid; 3 = ethyl lactate; 4 = pH; 5 = real extract; 6 = acetic acid, and sequence of microorganisms involved (Reprinted from Van Oevelen *et al.* 1977. *J. Inst. Brew.* 83:356-360). Guinard

AAR Fermentation Dynamics



data taken from Martens

Lambic Fermentation Dynamics



data taken from van Oevelen

Titratable acidity (TA) and pH, defined

pH	TA
like temperature	like heat
$-\log_{10}([H^+])$	how many molecules of acid, by weight
measures strength of acid	measures quantity of acid
determines biological activity	determines taste
use pH paper or meter	titrate with base to neutrality “how much drano do you add to your beer to get pH 7.0”

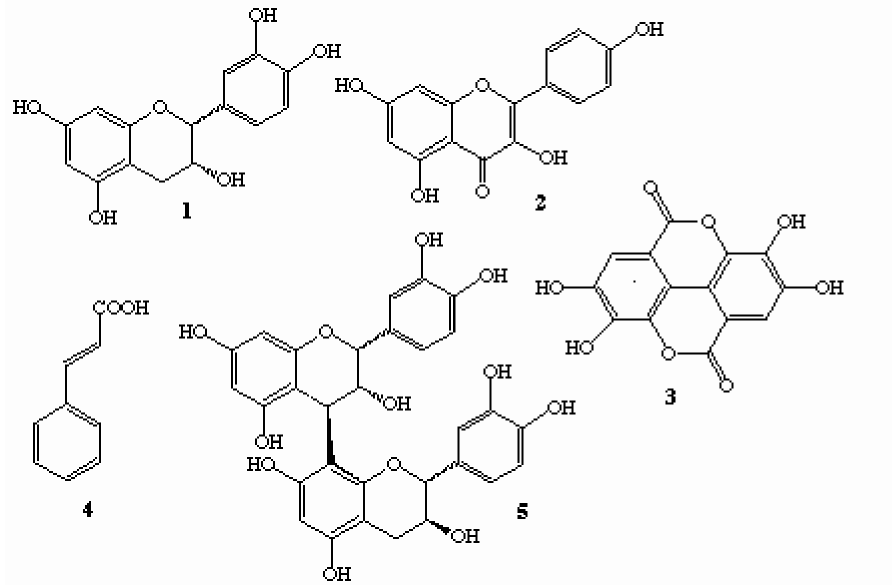
10,000ppm = 1%

1ml of 0.1N NaOH is equivalent to 9mg lactic acid

Acid	pK_{a1}	pK_{a2}	Mass/Mole
Tartaric	3.02	4.54	150
Citric	3.03	4.74	192
Malic	3.40	5.05	134
Lactic	3.86	--	90
Ascorbic	4.04	11.8	176
Acetic	4.76	--	60

	% abv	pH	TA tartaric w%
Leinenkugel lager		4.1	
Preston Merlot, 2000	13.5	3.5	0.6
Landskroon Chardonnay, 2003	13.0	3.0	0.7
Verhaeghe Duchesse	6.2	3.1	1.5
Petrus Aged Pale	7.3	3.4	1.0
Cantillon Iris	5.0	3.4	1.4
Hanssens Oudbeitje	6.0	2.8	1.5
Morte Subite Peche	4.3	3.6	0.7
Kriek de Ranke	7.0	3.5	0.7
Matadero Creek Cask Porter (me)	6.0	3.3	0.6
Matadero Creek Kriek (me)	6.0	3.5	0.8

Why use hops for low bitterness beer? Anti-Oxidant polyphenols



catechin (1), camphorol (2), ellagic acid (3), cinnamic acid (4), procyanidine B1 (5)

- Polyphenols come from hops and malts (tannins are polyphenols).
  - high usage of aged hops
  - high sparge temp.
- Anti-oxidants: no conclusive human health effects, but very important for flavor stability
- Saaz: 6% polyphenols, 3% alpha acids
- Bottle conditioning with yeast has anti-oxidant effect
- Cardboardy, oxidized flavour is prevented
- Contribute to haze (never drink a clear lambic)

Polyphenol, Czech Saaz	mg/100g
Hydroxy benzoic acids	1 - 10
Hydroxy cinnamic acids	100 - 450
Proanthocyanidins	100 - 600
Flavanoles	30 - 200
Flavonoles	1 - 10
Quercetine flavonoids	50 - 250
Camphorol flavonoids	50 - 300
Prenyl flavonoides	100 - 1000

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Sour Mashing, Papazian—NOT!

Lactic Souring

In gallon jug, mix 3L brewing water at 46C with 800g unmilled malt, seal with fermentation lock, hold at 46C for 2-3 days. If possible, inoculate with Lactobacillus delbrueckii or amylolyticus; or inoculate with grain.

- Lactobacillus is oxygen-tolerant; oxygen is toxic to Pediococcus
- Some L., eg L. amylolyticus, can digest starch and do not require mashing.
- At 46C very few other things will grow
- standard method of mash acidification for Reinheitsgebot brewing (addition of synthetic acids forbidden). Widely practiced for pale beers in Germany
- low ethanol, low IBU, low oxygen give more sourness

Acetic Souring

Orleans process: put beer in a jar, cover with cloth, and keep warm and dark. I have Brett also in the pot. Very useful for blending

Wood, Plastic and the Role of O_2

Material	Oxygen Permeability cc-mil/m^2-day-Bar
Wood, Oak	7200
High-density polyethylene HDPE	2325
Low-density polyethylene LDPE	8586
Polyethylene terephthalate copolymer PETG	400
Polypropylene PP	2526
Polycarbonate PC	4650
Nylon (not oriented)	79
Saran	2

Flextank.com

200L barrels admit 20cc/L of oxygen per year = 100cc/L air. For 20L carboy, that's 2L of air.

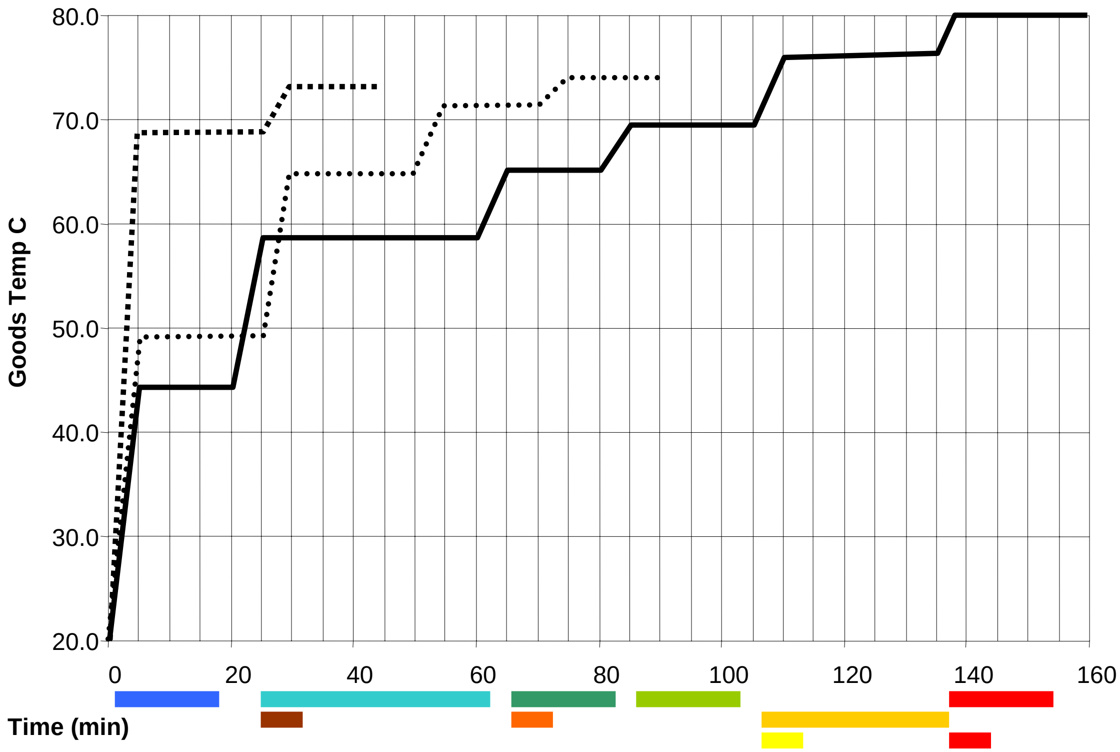
Brett will not thrive without oxygen. If you use cultured Brett, the large cell population can overcome this.

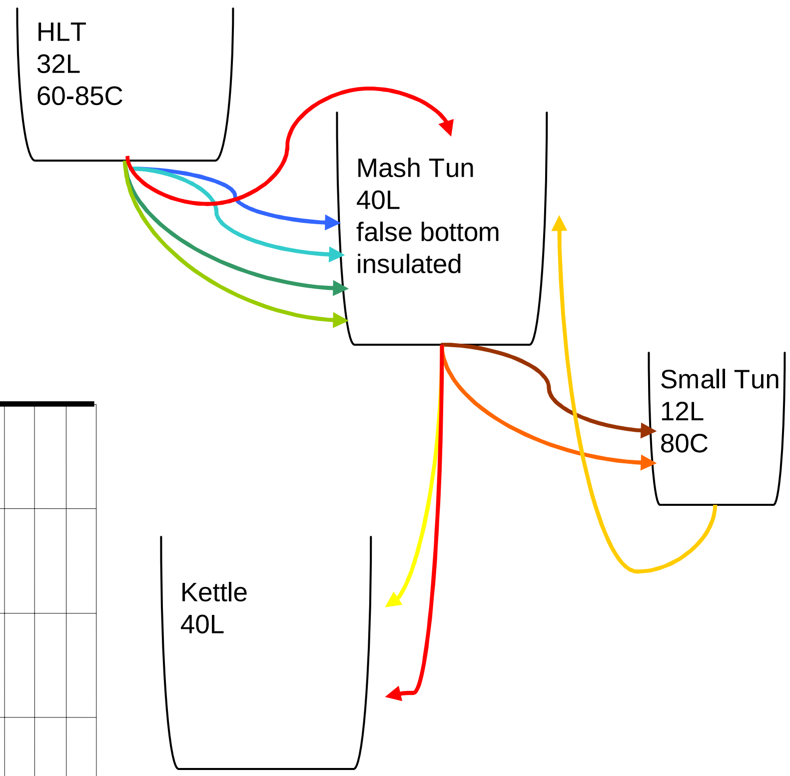
Custers effect = negative Pasteur effect = Brett needs O_2

Large casks at Rodenbach admit much less oxygen than 20L HDPE pail, much more than glass.

Turbid Mashing

Lambic/plambic only
30-40% raw wheat
Free Amino Nitrogen (FAN)
starch
tannins
high extraction eff.
works for very poorly modified malt





Brewing sour ales

- Mashing
  - Turbid or infusion mashing (high sacch. temp)
  - raw wheat, 30-40%, dark crystal
  - protein rests, high sacch. rest
  - hops 30-120g/20L. <15 IBU.
  - gypsum/carbonate to buffer (100ppm)
- Starting Fermentation
  - slow cooling: chill to 50C, pitch sour, hold until pH < 4.5
  - open window innoculation. enterobacteria—the sponge experiment
  - large doses of pure culture v. small inoculations
- Aging
  - primary or secondary lees
  - wood/plastic. bungs and topping off
  - late carbohydrate additions (corn or wheat starch, malt)
  - good ol' summertime
- Blending & Fruit
  - hard lambic, soft lambic, acetic lambic
  - running vinegar culture
  - traditional or novel fruits
  - late, do not age
  - carbonation levels, dryhopping

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