Brygning af øl

UNF workshop 4. marts. 2017

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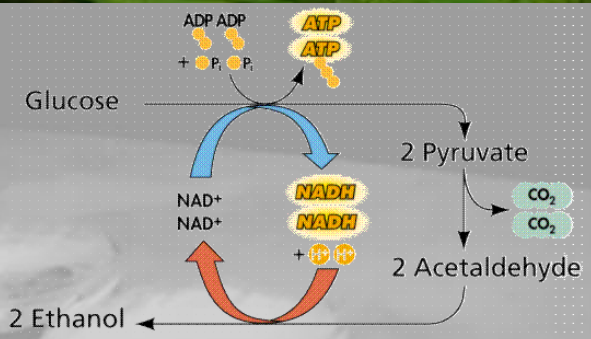
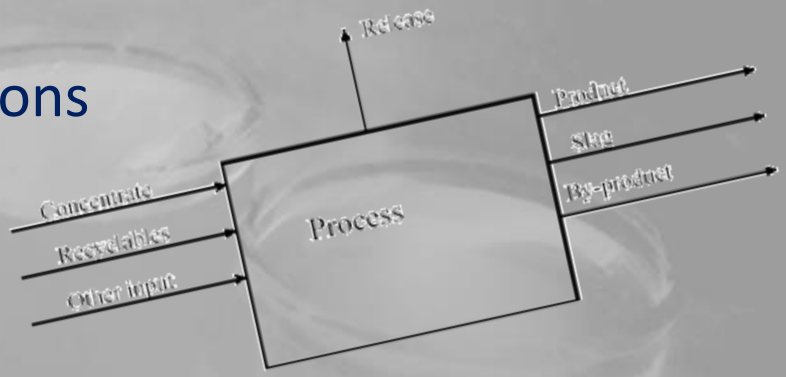
A course in Beer Brewing – why?

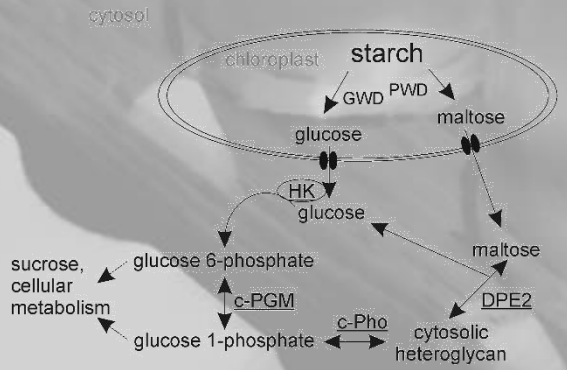
- Beer brewing is:
  - Fermentation



  - Great for mass balance calculations



  - Involves enzymatic reactions
  - Because…



Mads Sønderkær – the MSc PhD.

- 2008: MSc in Engineering in Biotechnology
  - *Gene Expression Profiles of ALS Porcine Models vs. Wild Type Controls*
- 2012: PhD in Engineering in Biotechnology
  - *Bioinformatic tools for next generation DNA sequencing – development and analysis of model systems*
- Associate Professor 2011 - 2014
  - *MAShed Potatoes: Genomics assisted potato crop development*
- Post Doc. 2014 - 2017
  - *Creating superior yielding potato by metabolic engineering of a novel starch synthesis pathway*
- 2017 – Aalborg Universitetshospital
  - *Senior Bioinformatician*

Mads Sønderkær – The Beer Brewer

- Brewer since 2007
  - +50 brews

The Process of Brewing Beer

- ***Malt*** and mashing
- Lautering and Sparging
- ***Hops*** and boiling
- Cooling
- ***Yeast*** and fermentation

Todays Agenda

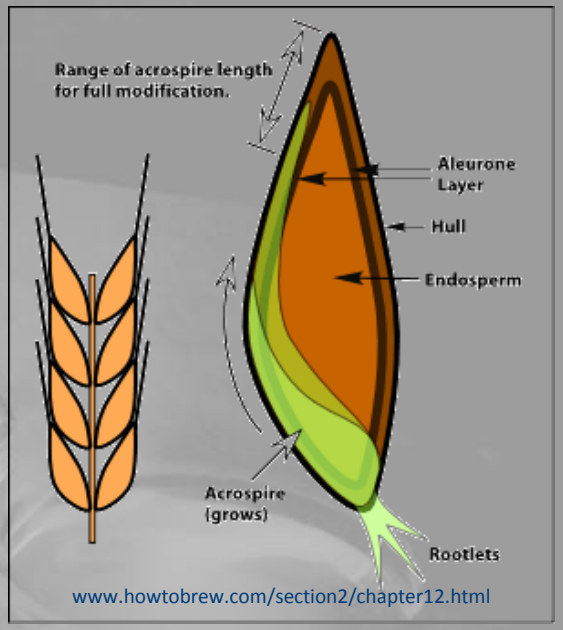
- Introduction to beers (~ ½ hour)
  - Types of beer
  - The process of making (good) beer
- Mashing (~ 1 hour)
  - Talk about malt and mashing
  - talk about Lautering and Sparging
- Lautering and Sparging (~ 1 hour)
  - Talk about hops and boiling
- Boiling (~ 1 hour)
  - Talk about cooling
  - Talk about yeast and fermentation
  - Talk about all the other stuff
- Cooling (~1 hour)
  - Time for questions
- Cleaning
  - (~ ½ hour – or until you are finished)

Ingredient # 1: Malt

- What is malt?

Ingredient # 1: Malt

- In short: Corn is made wet and allowed to germinate and the quickly dried.
- Barley is most frequently used
  - but also Wheat, rye and oat can be malted
  - Advantages of barley: has an appropriate amount of husk



www.howtobrew.com/section2/chapter12.html

- Outcome: A range of enzymes, which the plant uses to degrade the “lunch box” of the corn (mostly starch and protein) are activated.
  - The germination is stopped by the drying

Malting – a 3 step process

- **Steeping**
  - barley is immersed in water → encourage growth
  - The moisture content of the barley is increased from ~ 12 % to ~ 45 %
- **Germination**
  - Wetted grain is grown under controlled conditions
  - The internal structure of the grain is altered
  - sugars are produced from the grain's starch store
  - **Natural enzymes are developed within the grain kernel**
- **kilning (Drying)**
  - warm air is passed through the grain → halts the growth
  - color and flavor compounds are formed within the malt.

Malt: kilning

Malt – provides color and taste

- Malt types that are kilned at low temperature still contain active enzymes – these are called **basic malts**
  - Basic malts make up the major part of the malt composition
- High-kilned malts have experienced some enzyme breakdown
  - Introduces distinctiv[illegible] to the finished beer.

- The color of malt is given in two different units
  - EBC: European Brewing Convention (Europa)
  - SRM: Standard Reference Method (US)
  - EBC = SRM·1,97

Adjuncts (other sources of sugar)

- Adjuncts are most often different types of unmalted cereals

- Other sources of sugar can also be used
  - regular sugar
  - honey
  - Maize (Some Brazilian beers contain > 45 % maize).
  - Fruits

Brewing step # 1 Malt milling

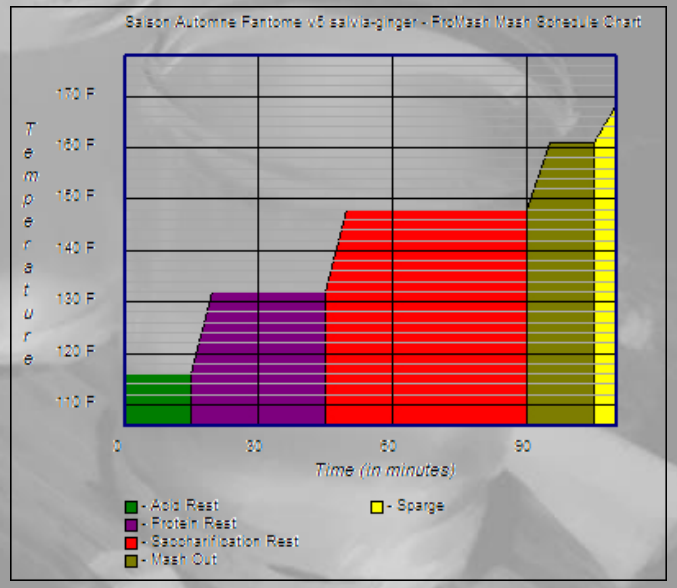
- **Purpose:** To better allow the mashing liquor to access the center of the barley
  - This allows the enzymes layer to act upon the starchy endosperm
- The grain husk should remain intact
  - Husks are used to form a filter bed during lautering
- **Product:** a range of fragments of barley
  - No whole grains (poor mashing due to less enzymatic action caused by a lower surface area of endosperm)
  - Little flour (leads to haze in the final beer)

Brewing step # 2: Mashing

- Milled malt is mixed with (hot) water

- **Primary purpose**: Conversion of complex starches into simple fermentable sugars
- **Secondary purposes:** Extract taste-aroma and color substances
- Product: wort

- Different enzymes in the malt will degrade starch and sugars
  - Enzymes have different temperature optimums
  - A mash schedule can be made

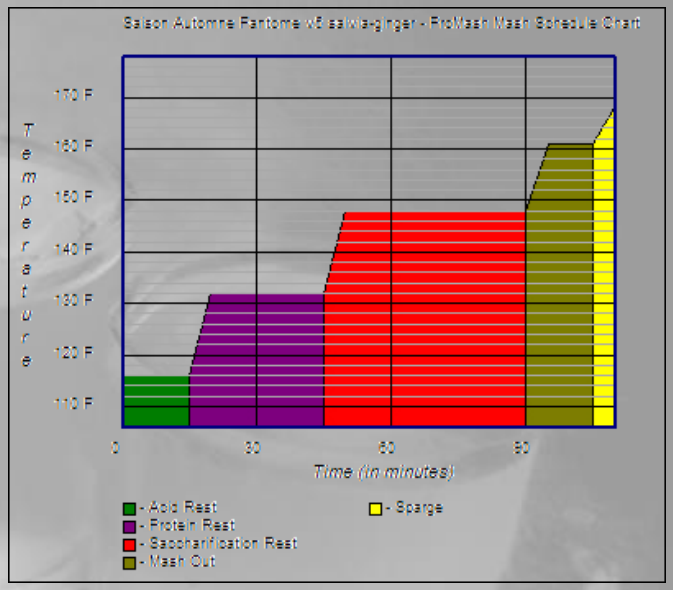


Types of Mashing I

- **Single Infusion Mash**
  - Room temperature crushed grains + premeasured amount of hot water at a fixed temperature.
    - Calculation of the volume and temperature of the water→ combined mash in the 64-70 °C range for 45-90 minutes
    - Typically done at a water to grain ratio of 2.6 v/w
- **Temperature Mash**
  - Mixed water and grains are simply raised to the target mashing temperature and held at that temperature until the starch conversion is complete.
- **Decoction Mash**
  - A small quantity of mash is brought to a boil and added back to the original mash to raise the temperature of the overall mash.
    - typically done at higher water to grain ratios of ~ 4.0 L/kg or more.
    - Traditionally used in Germany for many beer styles

Types of Mashing II

- **Multiple Step Mashes**
  - Initial infusion step to an **acid rest** at 40 °C. Lowering of pH
  - **Protein rest** at 50 °C. Help to break down proteins and complex starches in preparation for saccrification
  - **Saccrification** step at 68 °C. Break down of complex starches into smaller sugars (maltose)
  - **Mash out** at 75 °C. helps to halt saccirifcation, and also helps ensure an efficient sparge by extracting sugars at a higher temperature.



- Infusion mash is suitable in 95% of cases where modern well modified malts is used

Enzymes for Mashing: amylases

β-amylase

- Exo-amylase
- primarily produces maltose
- Temperature optimum ~ 62 °C

α-amylase

- Endo-amylase
- cuts amylose and amylopectin into smaller units of amylose and amylopectin
- Gives β-amylase more ends to "attack"
- Temperature optimum ~ 73 °C

Often a compromise between the optimal temperature and pH of α- and β-amylase is chosen for mashing. Typically 65-68 °C og pH 5.2-5.4

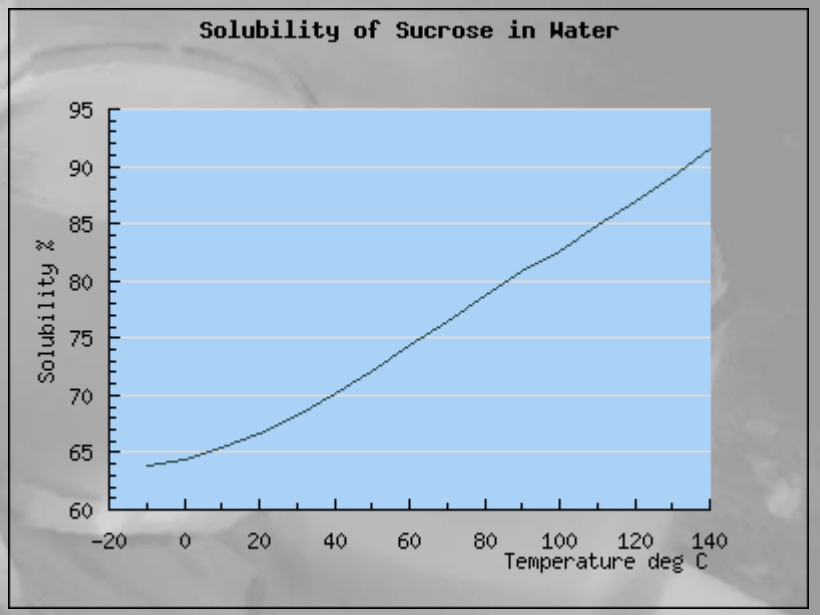
The product (wort) primarily consists of maltose maltotriose and glucose, but also a number of un-fermentable dextrins

Important Enzymes for Mashing

Enzyme	Function	Temperature [°C]	pH
Phytase	breaks down phytin into insoluble calcium and magnesium phosphates and phytic acid. **The process lowers pH.**	30-52	5.0-5.5
Debranching enzyme	Breaks down branches of amylopectin (starch). Enables a slightly larger mash efficiency.	35-45	5.0-5.8
β-glucanase	Breaks down β-glucan of cell walls. Can be used if you got > 25 % unmalted rye og wheat	35-45	4.5-5.5
Peptidase	Breakdown of proteins into amino acids. These are essential for yeast growth. Note that proteins are needed for a good stable foam ☺.	45-55	4.6-5.3
β-amylase	hydrolyzing starch and dextrins into maltotriose and maltose, but only works on ”twig” ends	55-65	5.0-5.5
α-amylase	hydrolyzing the straight chain bonds into dextrins, but it can attack them randomly,	68-72	5.3-5.7

Separation of the wort from the grain

- How would you separate of the wort from the grain?
  - We what as much sugar as possible!!



  - Rinse with hot water
    - Sucrose solubility:
      - 68 g/L at 25 °C
      - 79 g/L at 80 °C
      - 81 g/L at 95 °C
  - Why not rinse with 95 °C hot water?

Brewing step # 3: Lautering and sparging

- **Lautering:** Separation of the wort from the grain
  - The process where the sweet wort is run off from the mashed grains.

- **Sparging:** Rinsing of the grain
  - Extract as much of the sugars from the grain as possible without extracting tannins from the grain husks.
  - The temperature is raised to 76 °C → Stops amylase activity
  - The husk from the malt acts as a sieve
  - Sparging is done using 77 °C hot water
    - Extracts more sugar = more beer ☺
  - Max temperature: 80 C°
    - Otherwise tannins will be extracted
  - The wort is collected in the boiling pot

Ingredient # 2: Hops

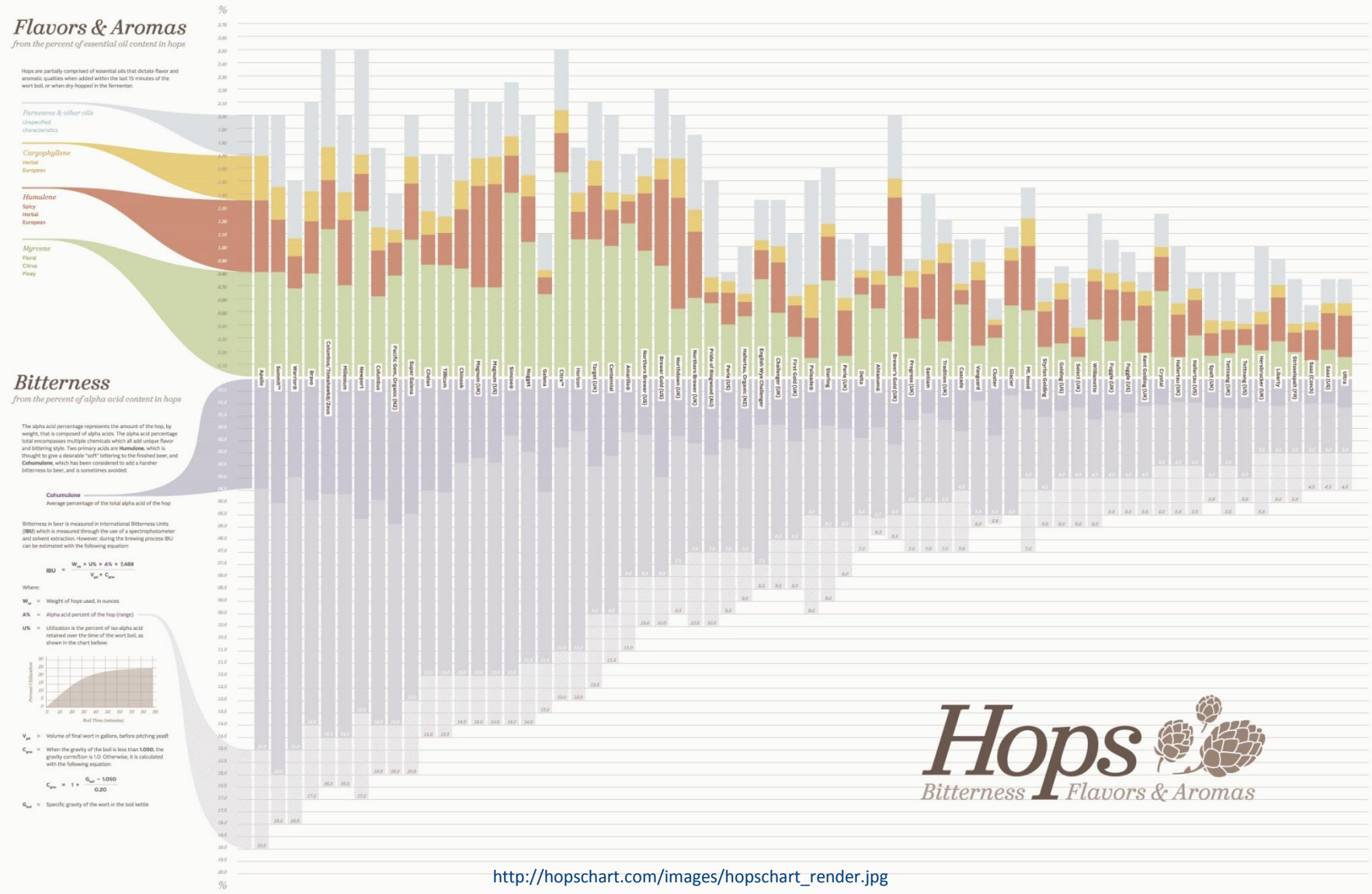
Ingredient # 2: Hops

- What is hops?

  - Hops are the female flowers of the hop plant *Humulus lupulus* -a climbing vine
    - The first documented hop cultivation was in 736, in the **Hallertau** region (Germany)

- what good does it do in beer?
  - Adds **bitterness flavor and aroma**
  - Acts as a stability agent / a natural preservative
    - Has an antibacterial effect
  - Aids in the development of a “hot break”
  - Aids in giving the beer a stabile foam

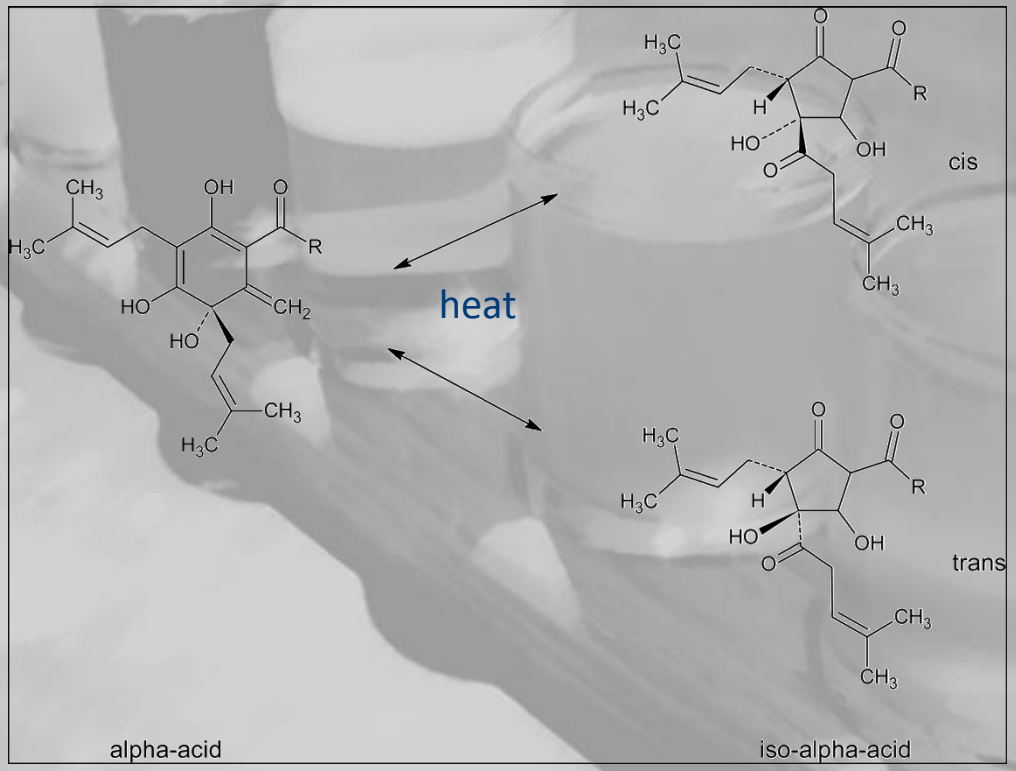
Hops – flavors Aromas & Bitterness



http://hopschart.com/images/hopschart_render.jpg

Hops - Bitterness

- Hops contains alpha acids
  - alpha acids go into solution almost immediately. However, the bitterness they impart to beer appears only gradually, as the alpha acids are slowly isomerized in the boil to form **iso-alpha acids** which gives the bitter taste.



Isomerization of α-acid, R denotes $-CH_2CH-(CH_3)_2$ (humulone), $-CH(CH_3)CH_2CH_3$ (adhumulone), or $-CH(CH_3)_2$ (cohumulone)

Hops – Flavor and Aroma

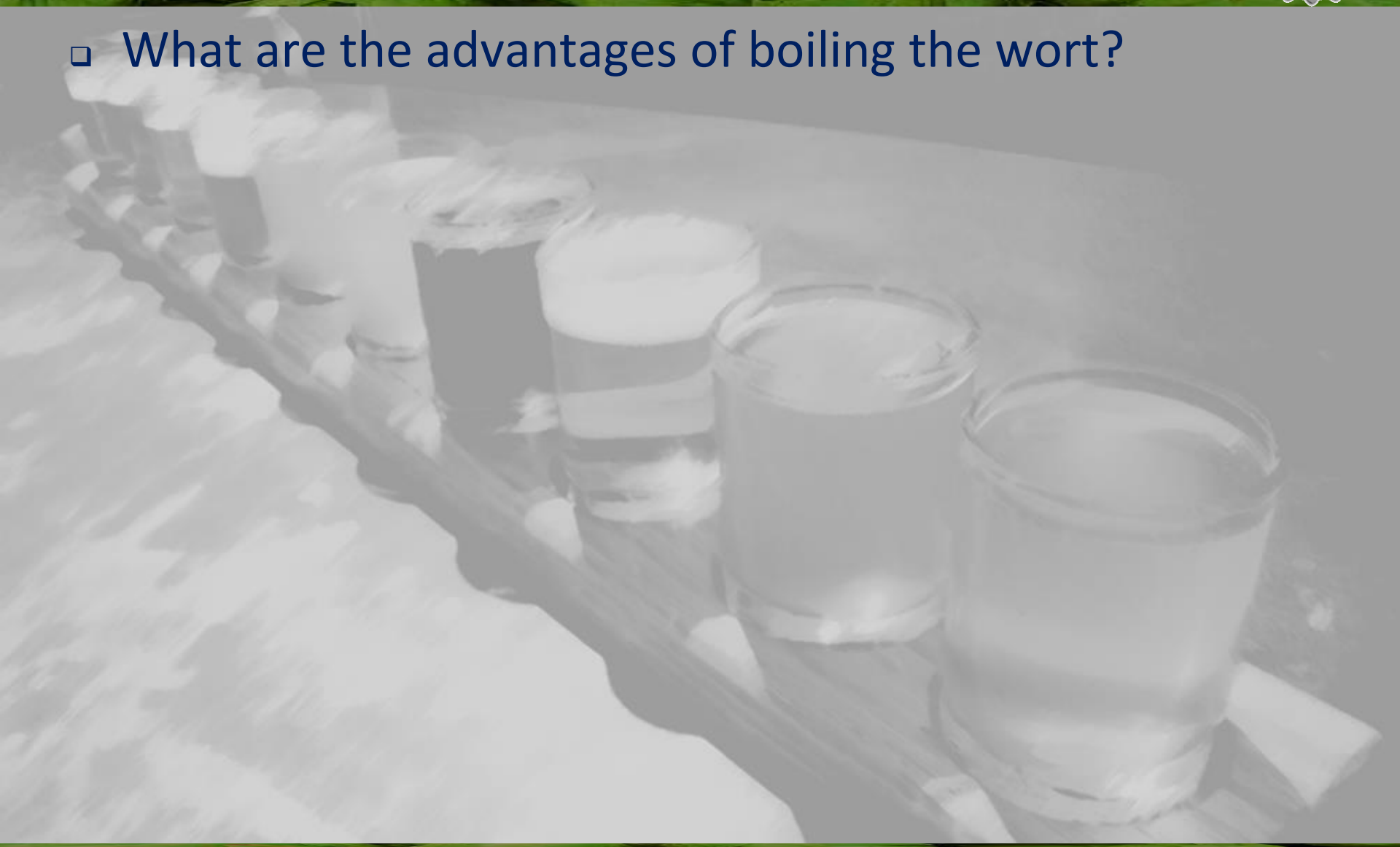
- Hops contains Essential oils
  - Most of the hop flavor and aroma is contributed by **volatile essential oils**.
    - **Humulene: Gives** the "noble" character to noble hops like Tettnang Tettnanger and Czech Saaz. Most bittering hop varieties have very low levels. Gives the “hoppy” aroma
    - **Myrcene** yields flavors not traditionally considered desirable by European brewers. Many American hop are very high in myrcene (Cascade 60%) (Amarillo 70%) and lends American hops many of their distinctive flavors. Also found in Cannabis Lemon grass and Thyme
    - **Caryophyllene** similar to humulene when boiled (it is an isomer of humulene. Its effect on flavor when fresh is not well understood.
    - **Farnesene: Unknown**

Hop Forms

Form	Advantages	Disadvantages
Whole	They float, and are easy to strain from wort. Best aroma character, if fresh. Good form for dry hopping.	They soak up wort, resulting in some wort loss after the boil. Bulk makes them harder to weigh.
Plug	Retain freshness longer than whole form. Convenient half ounce units. Behave like whole hops in the boil. Good form for dry hopping.	Difficult to use in other than half ounce increments. They soak up wort like whole hops.
Pellets	Easy to weigh. Small increase in isomerization due to shredding. Don't soak up wort. Best storability.	Forms hop sludge in boil kettle. Difficult to dry hop with. Aroma content tends to be less than other forms due to amount of processing.

Brewing step # 3: Boiling

- What are the advantages of boiling the wort?



Boiling: Hot Break and DMS

- A foam called “hot break is formed
  - Caused by proteins that coagulate
  - Yields a clear and stabile beer

- The wort is boiled without a lid – why?
  - All malts contain S-Methyl Methionine (SMM)
    - S-Methyl Methionine $\xrightarrow{\text{heat}}$ Dimethyl Sulfide (DMS)
  - DMS smells like: “cooked or creamed corn”, cabbage, sulfurous!

Boiling: Adding Hops

- Bitterness
  - Long time isomerization of **iso-alpha acids** gives the bitter taste.
  - “Bitter hops”: Normally 45-90 minutes
- Flavor
  - Adding the hops ~ midway through the boil yields → a compromise between isomerization of the alpha acids and evaporation of the aromatics → yields characteristic flavors of beer
  - Often, lower alpha variety hops are chosen
  - “Flavoring hops” Normally 10-30minutes
- Aroma
  - volatile essential oils gives the aroma
  - Aromatic hops: Normally 0-10 minutes
  - “Dry hopping“: Hops added during fermentation
    - increased hop aroma in the final beer.

Boiling: Adding clarifying Agents

- The clarity of homebrewed beer is cherished for many beer styles.
  - Fining agents added at the end of your boil step or later in the fermenter can help to rapidly clear your beer.
- Haze producing contaminants:
  - Suspended yeast
  - Proteins from the malt
  - Polyphenols from both hops and malt.
- Irish Moss
  - Derived from seaweed.
  - Added in the last 10-15 minutes of the boil to aid in coagulation and precipitation of proteins during the cold break.
- Gelatin, Whirlfloc Tablets, Chillguard…

Brewing step # 4: Cooling

- After boiling the wort is cooled to the fermentation temperature – how would you do it (Fast is good)?

- Rapid Cooling –what is it good for?
  - Stops the formation of DMS (which is no longer evaporated)
  - Rapid cooling forms a “cold break”
    - Caused by another group of proteins that need to be thermally shocked into precipitating out of the wort.
    - The lack of a cold break causes a “chill haze”.
- Add yeast → start fermentation

Ingredient # 3: Yeast

Ingredient # 3: Yeast

- What is yeast?
- A single-celled fungus (An eukaryote)
  - *Saccharomyces* = sugar fungus
  - Facultative anaerobe
    - **+ O_2: respiration**
    - **- O_2: Fermentation**
  - Reproduces asexually by budding
- Two species are used in beer brewing
  - Ale yeast: *Saccharomyces cerevisiae* (baker's yeast, brewer's yeast)
  - Lager yeast: *Saccharomyces pastorianus* (formerly known as *Saccharomyces carlsbergensis*)

Brewing step # 5 - Fermentation

- What is fermentation?

- sugar → acids, gases and/or alcohol in the absence of O_2

- Ethanol fermentation of glucose:

$$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$$

Saccharomyces cerevisiae

- **Ale yeast:** Used in weizenbier, porter/stouts, Belgian beers and lots more
- Fermentation temperature is often 18-24 °C
- Is NOT capable of metabolizing the di-saccharide melibiose
  - Ferments raffinose to melibiose og fructose (33% fermentable).
- Budding often happens within the first 48 hours of fermentation
- The formation of spores is common
- IS seen as long chains in a microscope
- Yields a more aromatic beer (e.g. Belgian styles)

Saccharomyces pastorianus

- **Lager yeast:** Used in pilsners, bocks, Oktoberfest beer and other lagers
- Fermentation temperature is often 9-16 °C
- Is capable of metabolizing the di-saccharide melibiose
  - Ferments raffinose to galactose, glucose og fructose (100% fermentable).
- Budding often does **not** happens within the first 48 hours of fermentation
- The formation of spores is **not** common
- Is seen as single cells or flocks in a microscope
- Gives a less aromatic beer than *S. cerevisiae*

Fermentation – Flavors and Aroma

- Besides ethanol, a long range of flavor and aroma compounds are produced
  - esters and phenols.

- Production of these depends on
  - Yeast strain
  - fermentation temperature
    - ↑ temperature = esters, phenols and fusel alcohols
    - (Fusel = bad liquor in German). Fusels are alcohols with more than 2 C-atoms (often 8).
  - The dimension of the fermenter
  - Pressure
    - ↑ pressure= esters, phenols

Fermentation – The Alcohol percentage

- Why is this equation not true for beer fermentation?

$$C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5OH$$

- Other thing are formed
  - Esters, phenols
  - New yeast cells
  - …
- The wort does not only consist of glucose

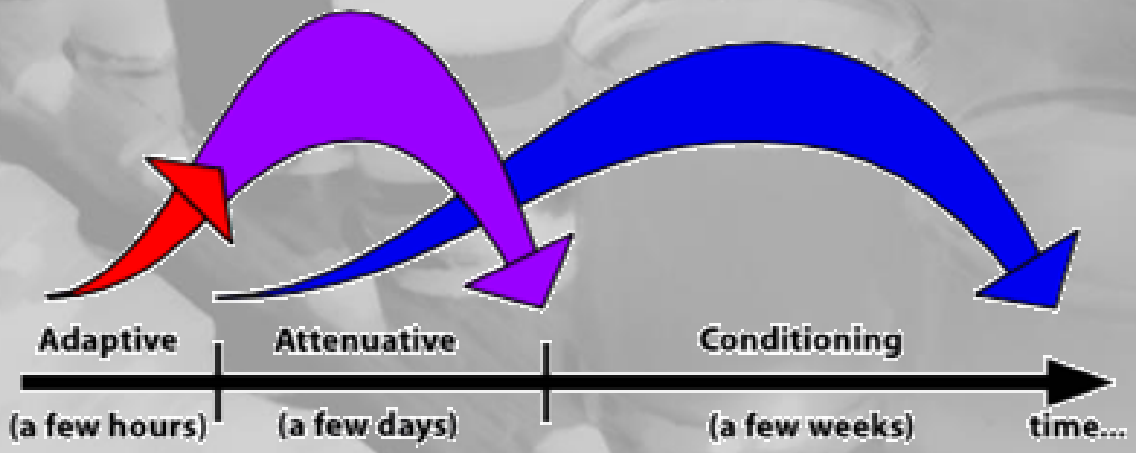
- Is has been experimentally determined that 1.05 g of ethanol is formed per g CO_2.

$$\text{ABV } \% = \frac{1.05 \cdot (\text{OG} - \text{FG})}{\text{FG} \cdot 0.79} \cdot 100$$

OG = original gravity, FG = Final gravity (before and after fermentation)

The Phases of Beer Fermentation

- Fermentation of malt sugars is more than just the conversion of sugar to alcohol.
- Can be split in three phases
  - **adaptive, attenuative and conditioning**



http://www.howtobrew.com/images/f51.gif

- Processes occur in parallel and overlap

The Phases of Beer Fermentation

- **Lag time / Adaptation Phase (a few hours)**
  - The yeast adjusts to the wort conditions
  - Undergo a period of high growth.
  - Use any available O_2 in the wort to facilitate growth
    - Phase can be shortened by an O_2 rich wort

- **Primary / Attenuative Phase(a few days)**
  - Vigorous fermentation
  - Gravity of the beer drops by 2/3-3/4 of the original gravity

- **Secondary / Conditioning Phase (a few weeks)**
  - Slow reduction of the remaining fermentable (ageing)
  - Consumption of compounds in the trub → off-flavors

- **Key to a good fermentation: lots of strong healthy yeast**
  - Get the job done before going dormant due to depleted resources, rising alcohol levels, and old age.

Yeast Starter – Yes or No?

- Hmm –yes, but I have not done it before…
  - but why?
- You need to start 2-6 days before you brew…
  - 1.5 dl malt extract in 0.5 L water → boil 10 min (last 2 with lid) ⇒ OG ≈1040
  - Cool to 27 °C and add to disinfected glass (1.5 L plastic bottle with airlock?)
  - Add yeast, cover with plastic film and shake, shake, shake (we need O_2)
  - Remove plastic film, add air lock, place in fridge (min. 1 day)
  - When the starter is clear, and the yeast lies at the bottom, it is ready

- Links
  - http://l.facebook.com/l.php?u=http%3A%2F%2Faal-bryg.dk%2Fdata%2Fuploads%2Ftema%2Fgaer_og_gaerstartere.pdf&h=RAQHCjr31
  - http://www.howtobrew.com/section1/chapter6-5.html
  - http://www.haandbryg.dk/klumme/teknisk_om_at_brygge.html
  - http://www.mrmalty.com/calc/calc.html
  - http://www.holbe.ch/vidensbank/gaerstarter-vaadgaer
  - http://www.holbe.ch/vidensbank/g%C3%A6rstarter-t%C3%B8rg%C3%A6r

Brewing step # 6 - Racking

- Transferring wort or beer from one vessel to another
  - Removes the beer from the krausen / yeast bed
- Benefits:
  - Reduce the risk of autolysis
  - Gives the beer time to clear

  - Done using a siphon

Brewing step # 7 – Cleaning bottles

- A home brewer's advice: "Clean after use, Sanitize before use". – John Palmer
- In the lab: Sterilization using an autoclave
  - Subjects high pressure saturated steam at 121 °C for ~ 15–20 minutes

- Sanitizing agents
  - Iodophor
  - bleach
    - **bottles most be rinsed with water that has been boiled! – why?**
  - boiling water

Brewing step # 7 – Cleaning bottles

- In the home brewery: Sterilization using an oven
  - Subjects steam at 150 °C for ~ 30 minutes
  -

Brewing step # 8 – Priming and Bottling

- How is the beer carbonated??

- At the brewery:
  - Fermentation occurs in pressure tanks – a controlled level of CO_2 can be retained in the beer

- At the home brewery:
  - forced carbonation (when using kegs)
  - Priming: addition of a small measured amount of sugar to their bottling bucket
    - The sugar is consumed by the yeast and CO_2 is produced.

Bottling

- Fill the beer using a siphon
  - Remember to leave a head space)
- Put the cap on the bottle and squeeze
  - Nothing much to it

Calculations - Priming

- The amount of sugar needed depends on
  - The type of beer
- Fermentation temperature
  - The original CO_2 volume varies with temperature
- The type of sugar used
    - Not all types are 100 % fermentable

Style	CO_2 volume
Ale	1.5-2.0
Porter, stout	1.7-2.3
Belgian ale	1.9-2.4
Lager	2.2-2.7
Lambic	2.4-4.5
Wheat	3.3-4.5

Type	Fermentability
Corn sugar	95 %
Cane sugar	100 %
Dried malt extract	55 %
Honey	84 %

Temperature	CO_2 volume
0	1.7
2	1.6
4	1.5
6	1.4
8	1.3
10	1.2
12	1.12
14	1.05
16	0.99
18	0.93
20	0.88
22	0.83

$$\mathbf{m_{priming\ sugar}[g] = V_{beer}[L] \cdot \left(Volume\ CO_{2_{final}}[L] - Volume\ CO_{2_{original}}[L]\right) \cdot \frac{4}{Fermentability}\left[\frac{g}{L^2 \cdot \%}\right] \cdot 100\%}$$

Calculations – The Alcohol Percentage

- It has been experimentally determined that 1.05 g of ethanol is formed per g CO_2.

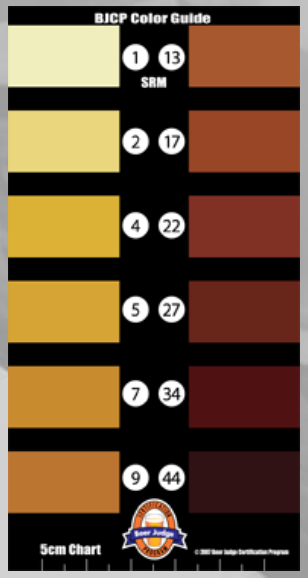
$$\text{ABV } \% = \frac{1.05 \cdot (\text{OG} - \text{FG})}{\text{FG} \cdot 0.79} \cdot 100$$

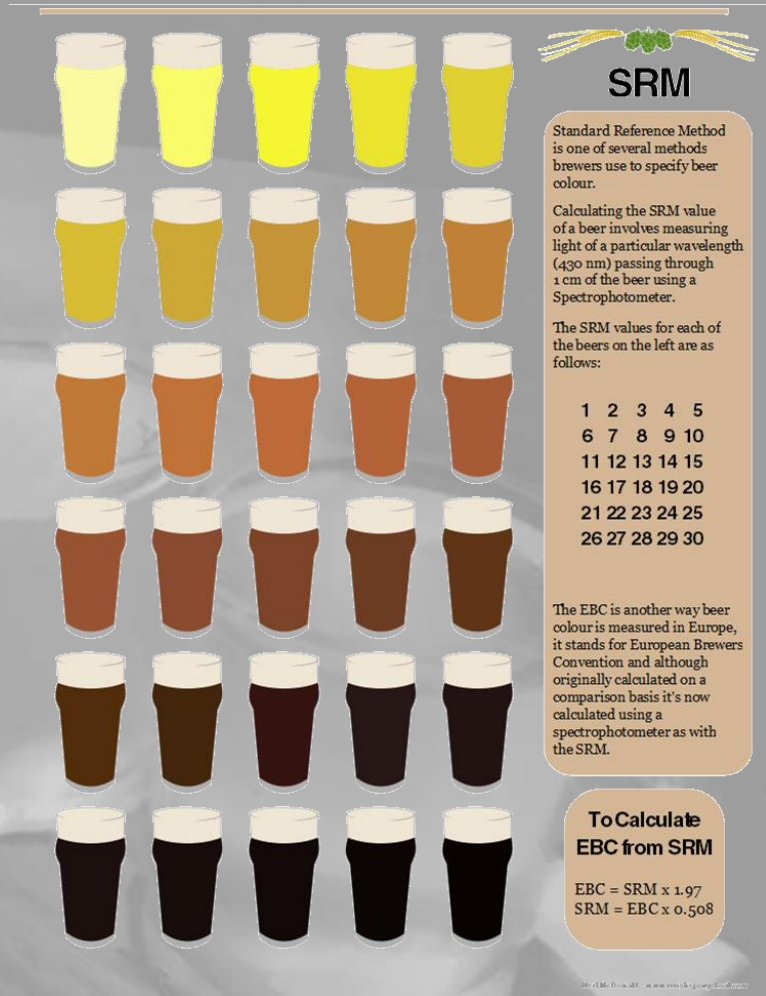
- Original gravity (OG) and Final gravity (FG) are measured using a hydrometer

Calculations - Color

- Measured by spectroscopy
  - Color [SRM] = A_{430} * 12.7 SRM
  - Color [EBC] = A_{430} * 25 EBC
  - why this wavelength?

- By visual inspection
  - bjcp color guide





Calculations - Bitterness

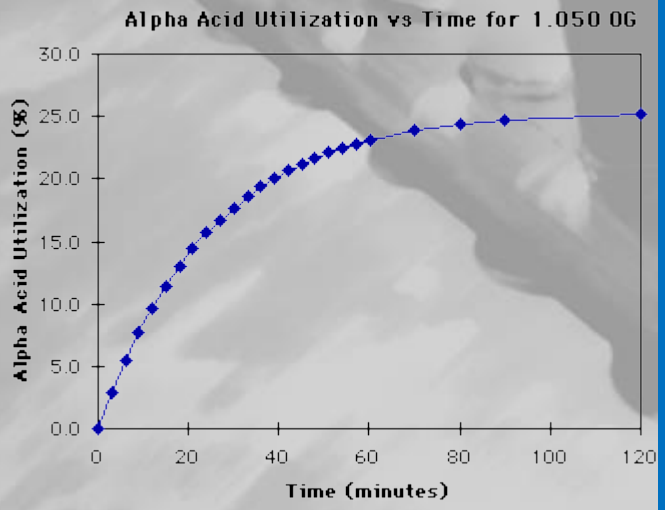
- IBU = International Bitterness Unit

$$IBU = \frac{m_{hops} \cdot U \cdot A\% \cdot 10}{V}$$

  - Where
    - m_{hops} = mass of hops [g]
    - U = Utilization (depends on boiling time and density of the wort) – see table
    - A% = Percentage of Alpha Acids in the hops [%]
    - V = Volume of the beer [L]
- An empirical model for alpha acid utilization was made by Glenn Tinseth (The Tinseth model)
  - http://realbeer.com/hops/research.html model
- Bitterness is summed for each addition of hops

Calculations - Bitterness

- The Tinseth model



Boil Time [min]	boil Gravity										
	1030	1040	1050	1060	1070	1080	1090	1100	1110	1120	1130
0	0.000	0.000	**0.000**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.034	0.031	**0.029**	0.026	0.024	0.022	0.02	0.018	0.017	0.015	0.014
6	0.065	0.059	**0.054**	0.049	0.045	0.041	0.038	0.035	0.032	0.029	0.026
9	0.092	0.084	**0.077**	0.07	0.064	0.059	0.054	0.049	0.045	0.041	0.037
12	0.116	0.106	**0.097**	0.088	0.081	0.074	0.068	0.062	0.056	0.052	0.047
15	0.137	0.125	**0.114**	0.105	0.096	0.087	0.080	0.073	0.067	0.061	0.056
18	0.156	0.142	**0.130**	0.119	0.109	0.099	0.091	0.083	0.076	0.069	0.063
21	0.173	0.158	**0.144**	0.132	0.120	0.110	0.101	0.092	0.084	0.077	0.070
24	0.187	0.171	**0.157**	0.143	0.131	0.120	0.109	0.100	0.091	0.083	0.076
27	0.201	0.183	**0.168**	0.153	0.140	0.128	0.117	0.107	0.098	0.089	0.082
30	0.212	0.194	**0.177**	0.162	0.148	0.135	0.124	0.113	0.103	0.094	0.086
33	0.223	0.203	**0.186**	0.170	0.155	0.142	0.130	0.119	0.108	0.099	0.091
36	0.232	0.212	**0.194**	0.177	0.162	0.148	0.135	0.124	0.113	0.103	0.094
39	0.240	0.219	**0.200**	0.183	0.167	0.153	0.140	0.128	0.117	0.107	0.098
42	0.247	0.226	**0.206**	0.189	0.172	0.158	0.144	0.132	0.120	0.110	0.101
45	0.253	0.232	**0.212**	0.194	0.177	0.162	0.148	0.135	0.123	0.113	0.103
48	0.259	0.237	**0.216**	0.198	0.181	0.165	0.151	0.138	0.126	0.115	0.105
51	0.264	0.241	**0.221**	0.202	0.184	0.169	0.154	0.141	0.129	0.118	0.108
54	0.269	0.246	**0.224**	0.205	0.188	0.171	0.157	0.143	0.131	0.120	0.109
57	0.273	0.249	**0.228**	0.208	0.190	0.174	0.159	0.145	0.133	0.121	0.111
60	0.276	0.252	**0.231**	0.211	0.193	0.176	0.161	0.147	0.135	0.123	0.112
70	0.285	0.261	**0.238**	0.218	0.199	0.182	0.166	0.152	0.139	0.127	0.116
80	0.291	0.266	**0.243**	0.222	0.203	0.186	0.170	0.155	0.142	0.130	0.119
90	0.295	0.270	**0.247**	0.226	0.206	0.188	0.172	0.157	0.144	0.132	0.120
120	0.301	0.275	**0.252**	0.230	0.210	0.192	0.176	0.161	0.147	0.134	0.123

IP80


TOTALLY AWESOME
IP80
IBU: 80
ABU: 8.0
An imperial IPA from
Bryghuset Sønderkær

Good manufacturing practice (GLP)

- Regular kitchen hygiene is required during most of the brewing process
  - The wort is boiled

- When should you be MOST careful – and why?
  - After cooling of the wort
  - Fermentation tank most be sterile

Beer Calc

- BeerCalc is a recipe calculator and database for the home brewer
  - Calculation features
  - Brew Logs
    - Log each time you brew a recipe, recording any variations.
  - Comments
    - Discuss with other brewers.
  - Style Guides
    - Compare of your target beer characteristics against BJCP, Danish, Swedish and Norwegian competition
- A short introduction
- http:// http://beercalc.org/
  - Username: UNFaalborg - Password: IloveIPA

Links

- Course material
  - http://sonderkar.dk/Downloads/UNF/
- Bryggerbogen (download on Moodle)
  - An “OK” intro to home brewing
- How to Brew – By John Palmer
  - All there is to know for a rookie brewer
  - http://www.howtobrew.com/
- Home Brew Talk – with a Wiki and forum
  - http://www.homebrewtalk.com
- Recipe calculator at håndbryg.dk (in English)
  - http://www.haandbryg.dk/cgi-bin/beercalc.cgi