Hops for Craft Brewers
Part 1: Bittering

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Conflicts of interest

- Owner/Operator The Island Hop Company LTD
  - *"Naturalized"* Continental European Varieties (Saazer, Tettnanger, Hallertauer, Magnum, USDA versions – ultra & santiam, etc)
  - New World (NZ) Varieties
- Consulting service
  - Recipe development and implementation
  - Troubleshooting

References

- Forster A et al. (2016) **Hopfen: Vom Anbau bis zum Bier.** Fachverlag Hans Carl
  - Link: https://www.amazon.com/Hopfen/dp/3418008089

- Bamforth C (2016) **Brewing Materials and Processes: A Practical Approach to Beer Excellence**. Elsevier.
  - http://my.mbaa.com/ItemDetail?iProductCode=99548

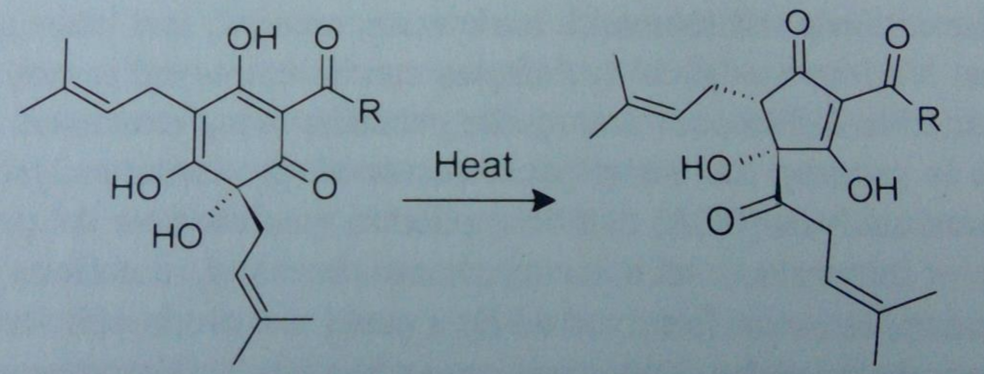
Outline

- *Always start from a position of honest humility.*
- Where does bitterness in beer come from?
- What is the "IBU"
  - Where it comes from
  - What it can help with
  - Where it can mislead…
- Troubleshooting Bitterness
  - What factors affect how bitter a beer becomes?
  - What factors affect the "harshness" of the bitterness? (intro to FWH)

“we don’t let the confines of the net stifle our creativity”

Where does bitterness come from?

- Isomerized alpha acids (iso-α-acids)
  - Cis-
    - More bitter
  - Trans-
    - Less bitter
    - More important for head stability
- Non-alpha acid sources
  - Beta-acids
  - Polyphenols
  - Tannins



Alpha acid

Iso-alpha acid

Fig. 2. Alpha acid isomerization at high temperatures. Side groups (R) designated humulone ($CH_2CH(CH_3)_2$), cohumulone ($CH_2CH_3)_2$), and adhumulone ($CH(CH_3)CH_2CH_3$) and their isomerized counterparts.

The International Bitterness Unit

- **The amount of iso-α-acid (mg/L) in the finished beer**
  - Direct measurement
    - Spectrophotometer – measure UV spectrum absorption
    - Iso-octane is mixed w the beer
    - Amount of light absorbed α to the amount of iso-α-acid in the beer

IBU calculation

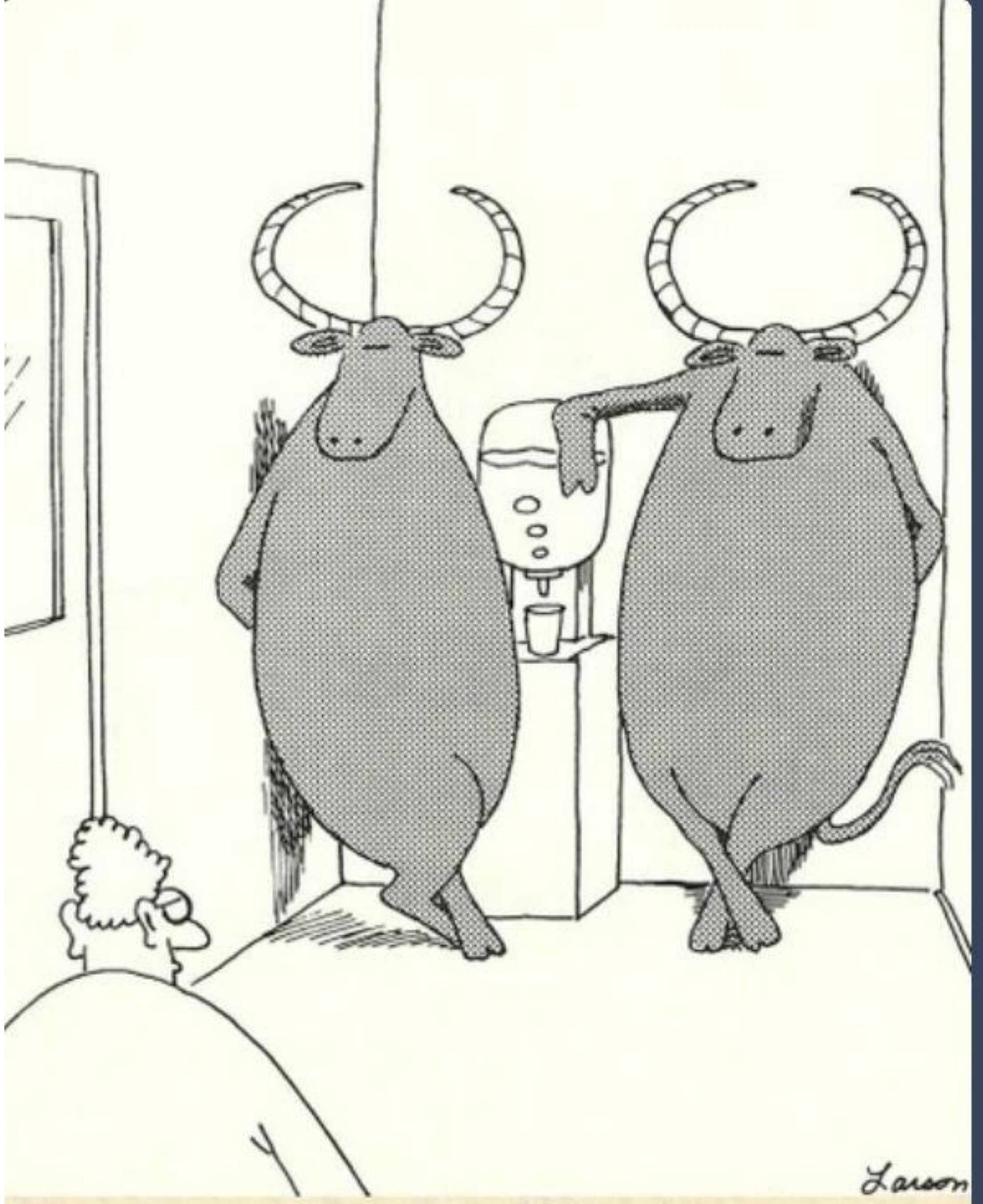
- Boil volumes
- Wort gravity
- α-acids added
  - or percent iso-α-acid and the amounts
  - When added
- Utilization

$$IBU = \frac{W_{grams} \times U\% \times A\% \times 1000}{V_{liters} \times C_{gravity}}$$

I’m not getting the bitterness level that I am intending consistently…

Know your water profile!

- <u>Control your water profile!</u>
  - Sulfate content – tremendous impact on hop flavour
    - Dortmunder Export (dry, high hop flavour, w harsher bitterness)
  - Chloride – sweet/rounded flavour that accentuates malt
  - Sodium – can be perceived as sweet in low amounts
  - pH
    - Ca, Mg
    - HCO3 - - increases harshness/sharpness of hop bitterness
  - Ratios
    - Sulphate:chloride
- Test Routinely!!! *(minimum once/year)*
  - Water content changes REGULARLY
  - **There's only so much hops, barley and yeast can do…**



Water buffaloes

Don’t feel alone…

- Utilization of iso-α-humulone is 50-60% in usual circumstances
- <u>**Loses everywhere**</u>
  - **REQUIRED** removal of vegetal material removes significant proportions of iso-α-humulone

Table 1. Concentrations of hop components that may have a flavor impact in beer[a]

Alpha acids	1–18%
Beta acids	1–16%
Essential oils	0.5–3.5%
Polyphenols	2–5%

[a] Data from Benitez et al., 1997; Verzele and DeKeukeleire, 1991.

Factors affecting solubility of alpha-acids

- Hop Chosen (%aa)/Hopping rate
- Hop Form (Pellet, Plugs, Whole Cone)
- Container used (e.g.)
- Boil conditions (temperature, vigor)
- Boil time vs hop introduction time
- Boil Volume
- Wort Gravity
- Wort pH
- Hopping rate during fermentation
  - Presence and concentration of ethanol
- Yeast growth and flocculation characteristics
- Filtration?

Temperature is king

- < 80 degrees
  - Minimal/VERY slow isomerization occurs
- 90 degrees (also Whirlpool)
  - Notable, but low level isomerization
- 100 degrees
  - Signification isomerization occurs with *maximal extraction occurring by 4 hours*
  - 90 minute boil
    - First 20 mins - 58% of isomerization
    - Final 70 minutes - final 42% 120 C (Hyperbaric)

- @100 degrees
  - 60 minute boil
    - 20 minutes - 66% occurs
    - 40 minutes - 33% occurs
  - 90 minute boil
    - Increase total isomerization by 14%

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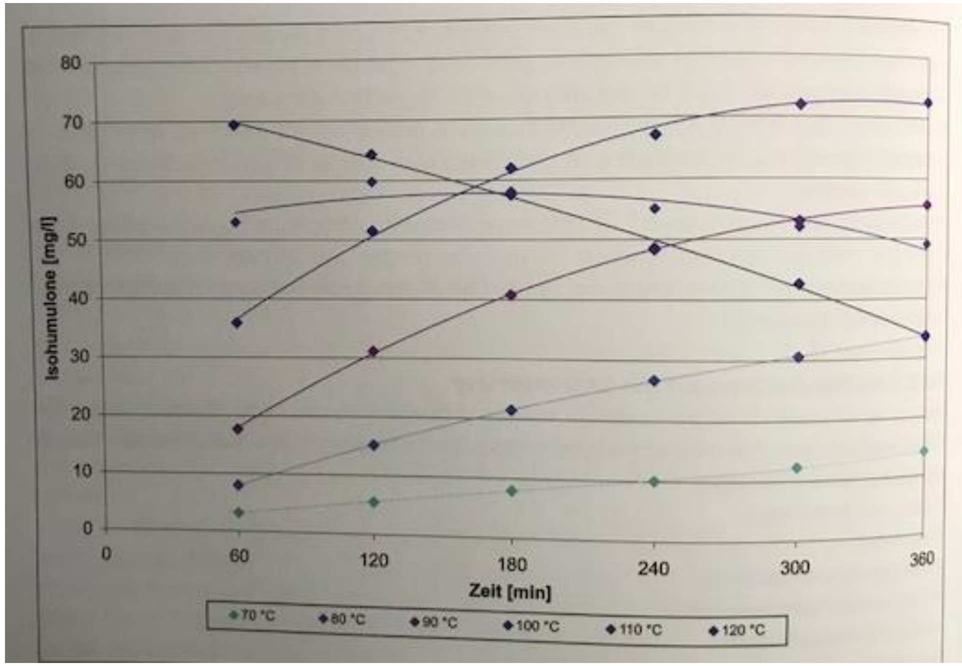
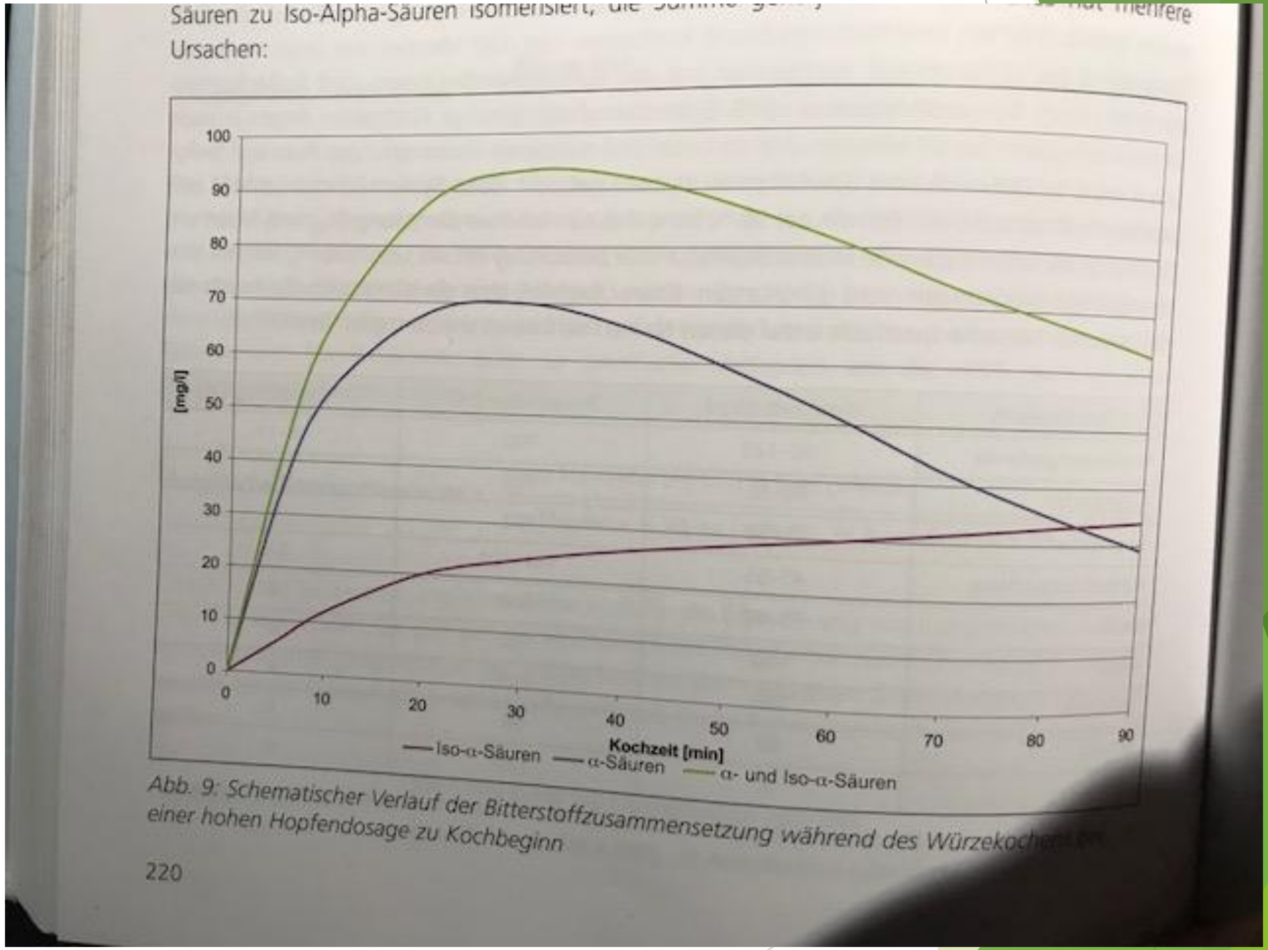


When does maximal iso-α-acid presence in wort occur?

- 120
  - 20-60 minutes
  - Drops by 8%/hr (non-linear w increasing losses with time)
- 110
  - 3 hrs
  - Drops minimally after, only increasing significantly after 5 hrs
- 100
  - 4 hrs
  - Maintainenance of max concentration until past 5 hrs



Make sure you have the best possible information

- Practical points:
  - Closely monitor temperature during additions. (the information is only as good as the instrument measuring it)
    - How accurate is your reading?
    - Where is the probe? (location)
    - **Is the probe clean and in top working order?**
  - Ensure temperature *at or above* 100C
  - The higher the temperature the more efficient the isomerization process.

Wort pH

- The higher the pH (within usual wort values: 4.8-6.0) the better the total iso-α-acid solubility.
  - Not linear
    - 5.2-5.4 – 8% increase
    - 5.6-5.8 – 12.5% increase
    - Decreasing influence over pH >6.2
- Practical point
  - Monitor wort pH prior to boiling and record.
  - In cases where loses are occurring consider raising mash pH to 5.6-6.0

pH	β-Säuren	α-Säuren	Iso-α-Säuren
5,6	8	200	3.000
5,2	1	84	2.000
4,8	<1	24	1.000
4,4	Spuren	10	300
4,0	–	4	120

Tab. 11: Anhaltswerte zur Löslichkeit (mg/l) von β-, α- und Iso-α-Säuren in Bier in Abhängigkeit vom pH

Types of hops

- Actual hops + plant matter
  - Whole leaf & Pellets (T90 and **T45**)
  - Time required to break down the plant matter and so get access to the lupulin glands → get them into solution (surface area)
- Extract
  - Increases isomerization by 10-15%
  - Near immediate isomerization (technically an infinite surface area)
  - Cost effective?

Hop storage index

- Based on:
  1. Type of hop
     - Cascade versus Newport
     - locally calculated numbers
  2. Time since harvest
  3. Storage conditions
     - CO2/N2 packed
     - Temperature
     - Light exposure (opaque packaging)
- Determines
  - How much α- and ß- acid remains in the hops
  - The relative concentrations of oxygenated versus non-oxygenated hydrocarbons exist.

$$A_f = A_0 * (1 / e^{(k*TF*SF*DAYS)})$$

riginal alpha ... hops is

% Lost	k	% Lost	k	% Lost	k
10%	0.00059	27%	0.00175	44%	0.00322
11%	0.00065	28%	0.00183	45%	0.00332
12%	0.00071	29%	0.00190	46%	0.00342
13%	0.00077	30%	0.00198	47%	0.00353
14%	0.00084	31%	0.00206	48%	0.00363
15%	0.00090	32%	0.00214	49%	0.00374
16%	0.00097	33%	0.00222	50%	0.00385
17%	0.00104	34%	0.00231	51%	0.00396
18%	0.00110	35%	0.00239	52%	0.00408
19%	0.00117	36%	0.00248	53%	0.00419
20%	0.00124	37%	0.00257	54%	0.00431
21%	0.00131	38%	0.00266	55%	0.00444
22%	0.00138	39%	0.00275	56%	0.00456
23%	0.00145	40%	0.00284	57%	0.00469
24%	0.00152	41%	0.00293	58%	0.00482
25%	0.00160	42%	0.00303	59%	0.00495
26%	0.00167	43%	0.00312	60%	0.00509

Storage Conditions	SF
Not sealed or sealed in poly bags	1
Sealed in barrier packaging or airtight jars, but not free from oxygen	0.75
Sealed in barrier packaging or airtight jars under a vacuum or inert atmosphere such as nitrogen or carbon dioxide	0.5

Storing Hops

Temp C	Temp F	TF	Temp C	Temp F	TF	Temp C	Temp F	TF
20	68	1.000	3	37.4	0.456	-14	6.8	0.208
19	66.2	0.955	2	35.6	0.435	-15	5	0.198
18	64.4	0.912	1	33.8	0.416	-16	3.2	0.189
17	62.6	0.871	0	32	0.397	-17	1.4	0.181
16	60.8	0.831	-1	30.2	0.379	-18	-0.4	0.173
15	59	0.794	-2	28.4	0.362	-19	-2.2	0.165
14	57.2	0.758	-3	26.6	0.345	-20	-4	0.157
13	55.4	0.724	-4	24.8	0.330	-21	-5.8	0.150
12	53.6	0.691	-5	23	0.315	-22	-7.6	0.144
11	51.8	0.660	-6	21.2	0.301	-23	-9.4	0.137
10	50	0.630	-7	19.4	0.287	-24	-11.2	0.131
9	48.2	0.602	-8	17.6	0.274	-25	-13	0.125
8	46.4	0.574	-9	15.8	0.262	-26	-14.8	0.119
7	44.6	0.548	-10	14	0.250	-27	-16.6	0.114
6	42.8	0.524	-11	12.2	0.239	-28	-18.4	0.109
5	41	0.500	-12	10.4	0.228	-29	-20.2	0.104
4	39.2	0.477	-13	8.6	0.218	-30	-22	0.099

HSI sample

$$A_f = A_o * (1 / e^{(k*TF*SF*DAYS)})$$

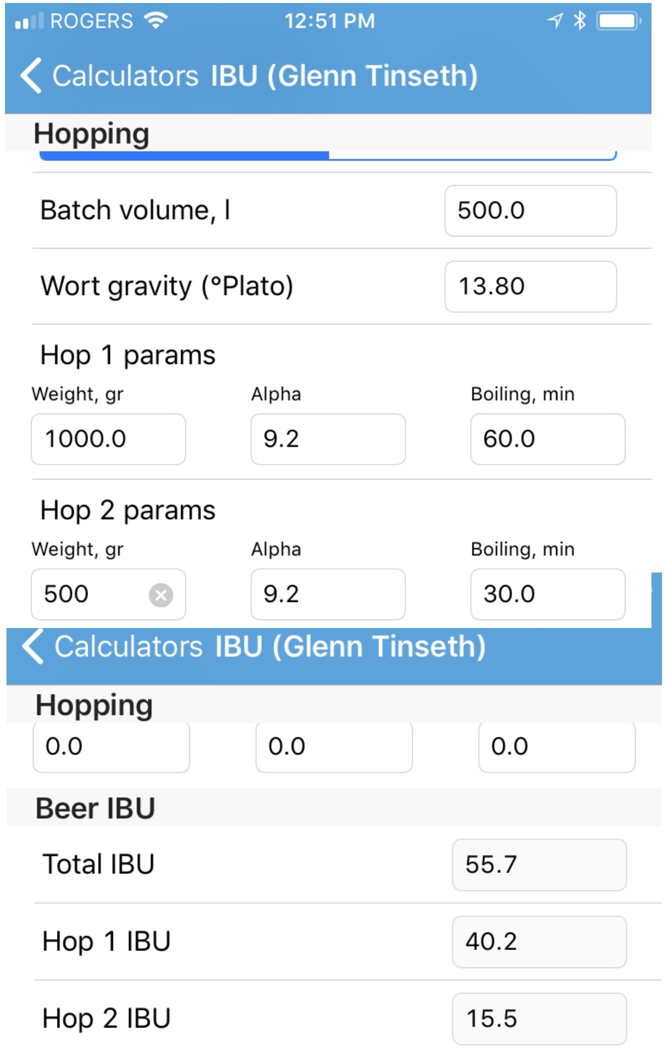
- Cascade (6.4%) harvested September 2017
- K – 0.00363
- Room temperature
- N2 flush packed

- (0.00363)(0.871)(0.5)(169)
- (0.267)
- 1.306
- (6.4%)(0.765)
- 4.8%

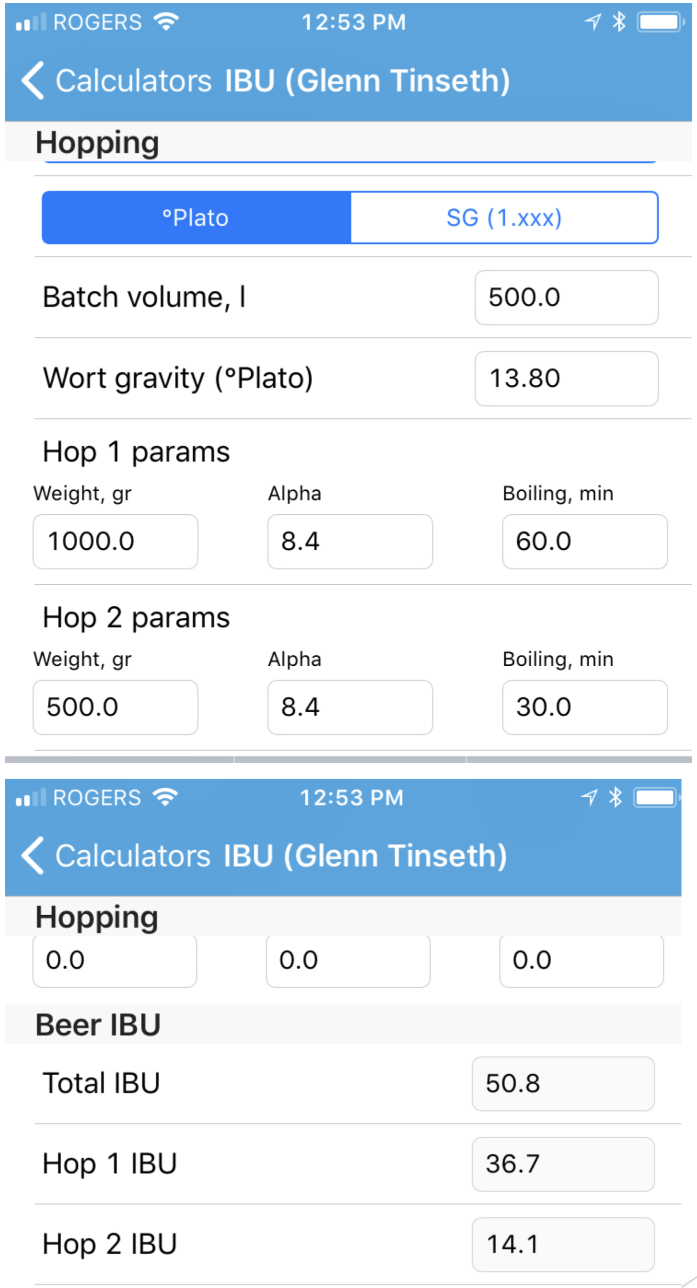
- Newport (9.2%) harvested September 2016
- K – 0.00284
- -2 degrees
- N2 flush packed

- (0.00284)(0.362)(0.5)(169)
- (0.0869)
- 0.917
- (0.917)(9.2)
- 8.4%

So WHAT?



October 2018



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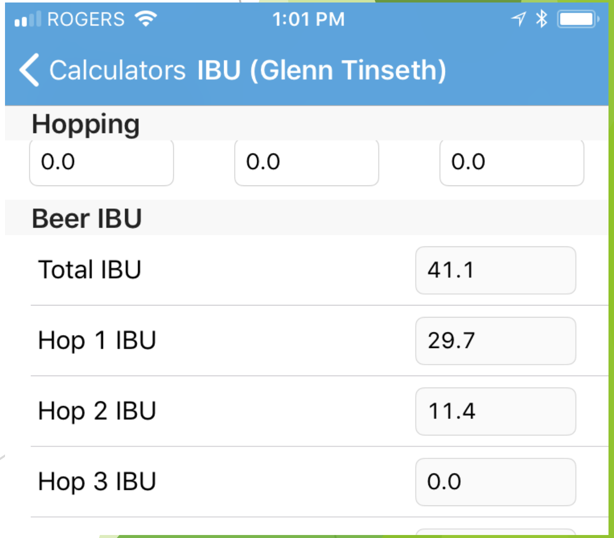
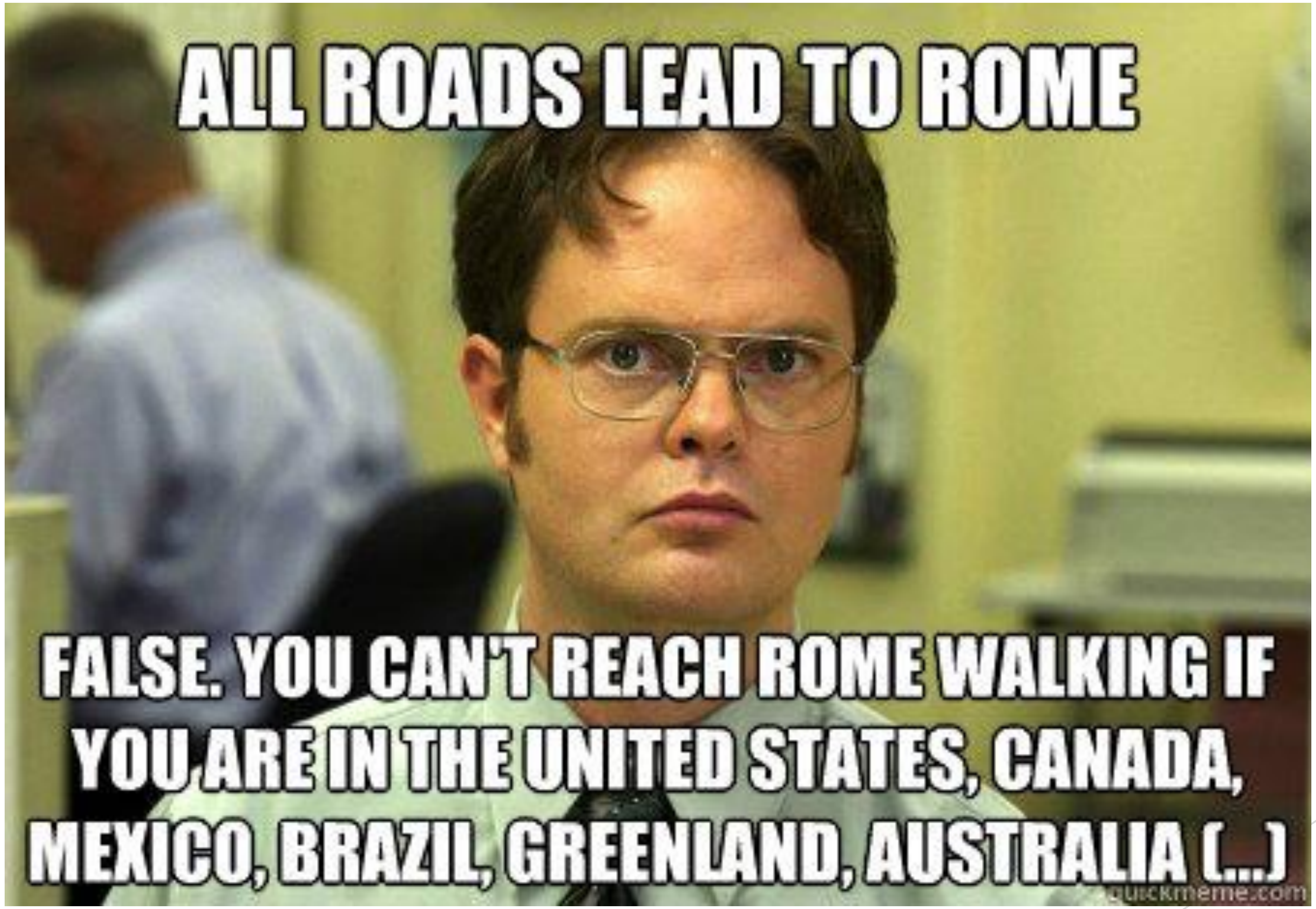


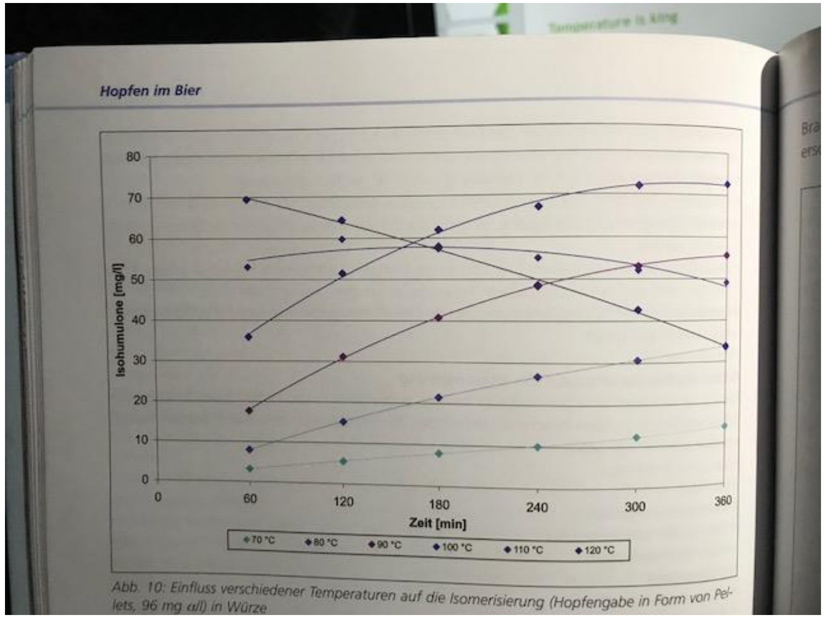
July 2018

Key quality indicator…



The law of diminishing returns

- The more you add (past 2 g α-acid/hl) the lower your utilization rates/the more you will waste
- Not the "COME AT ME BRO" situation
  - Definitely increased availability can be achieved through controlling other mechanisms
    - Temperature
    - pH
    - Time
    - Controlling the HSI

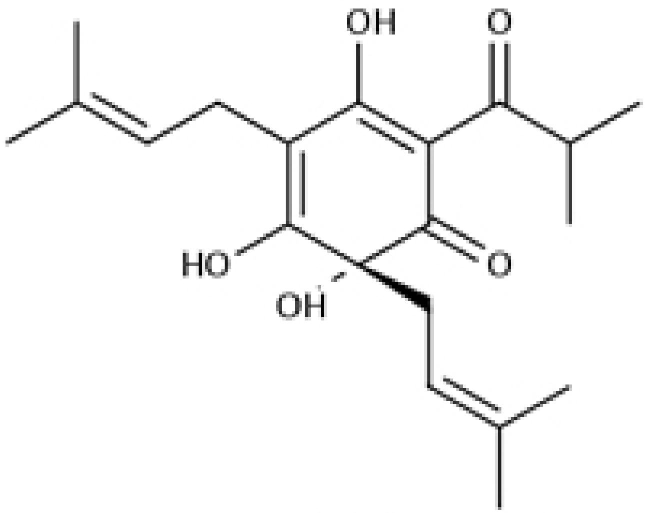


Filtration/Fining (just touching on this)

- Filters
  - Different types
  - Although time dependant - Rapid satiation of the filtration membrane occurs.
- Fining Methods
  - Isinglass
  - Gelatin
  - Carrageenan/Irish Moss

What about co-humulone?

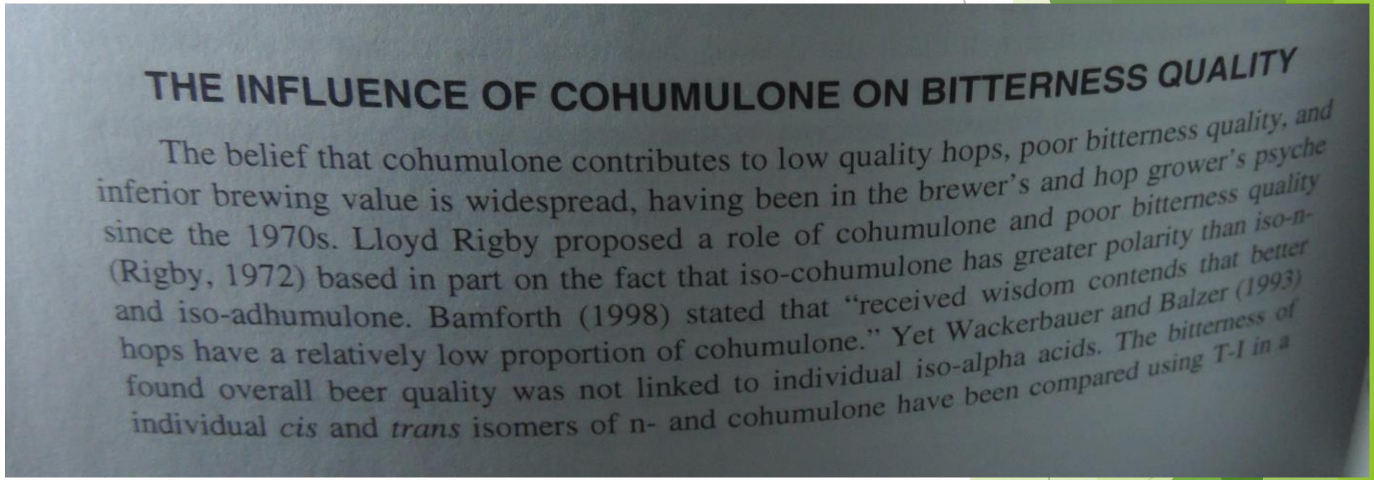
- ?Harshness in bitter?
  - Lower co-humulone levels seem to relate to “smoother” bitterness??
  - Less bitter
  - Factors that lower it
    - Boil time
    - 70-90 degree range
- First wort hopping
  - Lower cohumulone levels – “smoother more delicate bitterness” – REALLY?
  - “harsher bitterness” fitting for some styles?



Cohumulone

Co-humulone role in bitterness?

- Traditional thot
  - "harsh" bitterness
- Recently coming under question
  - Standardized brewing
  - High cohumulone hops did not correlate to poor bitterness/sensory performance of beer.
- **Practical point:** Don't make a decision on bittering hop SOLELY on co-humulone level… (you can give Topaz a chance)

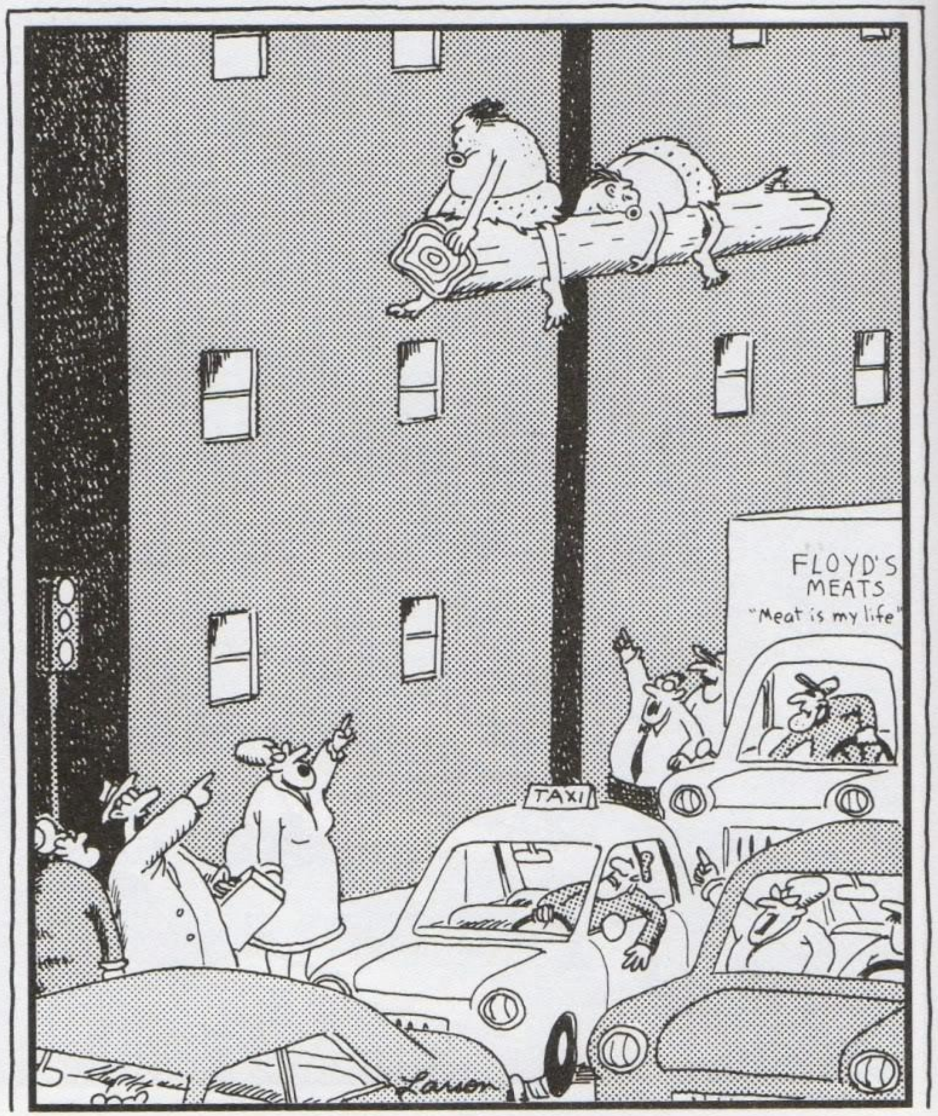


THE INFLUENCE OF COHUMULONE ON BITTERNESS QUALITY

The belief that cohumulone contributes to low quality hops, poor bitterness quality, and inferior brewing value is widespread, having been in the brewer's and hop grower's psyche since the 1970s. Lloyd Rigby proposed a role of cohumulone and poor bitterness quality (Rigby, 1972) based in part on the fact that iso-cohumulone has greater polarity than iso-n- and iso-adhumulone. Bamforth (1998) stated that "received wisdom contends that better hops have a relatively low proportion of cohumulone." Yet Wackerbauer and Balzer (1993) found overall beer quality was not linked to individual iso-alpha acids. The bitterness of individual *cis* and *trans* isomers of n- and cohumulone have been compared using T-I in a

Summary: Key Common Issues

1. A lot of issues can be resolved by knowing, routinely testing and controlling your water profile.
2. Knowing the HSI for the hops that you have purchased
3. Knowing, accurately measuring and controlling your mash pH
4. Controlling boil temperature and use to maximize utilization
5. More isn’t always better (don’t come at me bro)
6. Don’t restrict your bittering hop choices too much…
7. Don’t judge people who use extracts to HARSHLY



Hooting excitedly, primitive scientists Thak and Gork try out their new “Time Log.”

Some personal advice

- Be Humble
  - Ask for help
  - Confidential resources (myself, CCNB, etc)
- Be Patient
  - We ALL make mistakes
  - Brewing and beer farming is by definition a **GENERATIONAL** pursuit.
- Be Persistent
  - Don’t expect your genius to be fulfilled in every brew
- Be Purposeful
  - See involvement of industry experts as investment (certified cicerone, CCNB, etc)
  - Continuing Education

Some wise words

Beyond the mountains there are more mountains (Haitian Proverb) Basically – theres lots for us all to learn!

Wissen ist macht (knowledge is power)

Hopfengarten („Stockgarten") aus der ersten Hälfte des 19. Jahrhunderts

Thank you!

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