BARTH-HAAS GROUP

Beer Diversification by efficient Dry Hopping

Georg Drexler, Brewing Solutions

Dry Hopping

- Around 30-35% of US Craft Beers are IPAs („regular“, New England/Hazy, Session, Double…)
- Lot more beers than IPAs are dry hopped (Pale Ales, some Lager/Pilsner, Experimentals etc.)
- US Craft beer: >50% dry hopped?!
- Dry hopping is very popular, but still not fully understood
- Dry hopping itself is not a unique selling proposition

=> Need and opportunities for improvement

Agenda

- Diversification – relevant hop compounds
- Efficient dry hopping
- Provoak

Important Hop Aroma Compounds

- Linalool: „Key Aroma Compound“?
- Depends on
  - which varieties are used?
  - at which stage in the brewery?
  - at which dose rate?
- If we talk about…
  - Traditional, late hopped beer styles (low in hop aroma) – Maybe!
  - hoppy craft beers with flavour hops – NO!
- What about Thiols?

Hop Oil Composition

440 compounds identified, 1000 + are likely!

Substance Group	Concentration
Monoterpenes (myrcene, pinene etc.)	approx. 40 %
Sesquiterpenes (ß-caryophyllene, α-humulene)	approx. 40 %
Carboxylicacid-esters (methyl-esters)	approx. 15 %
Carboxylicacids	approx. 1 %
Monoterpenoxides (linalool, geraniol etc.)	approx. 1 %
Sesquiterpenoxides (humullenol II, humulen epoxides)	approx. 1 %
Aldehydes, Ketones (hexenal, epoxydecenal, undecanone, octadienone)	approx.1 %
Aliphatic hydrocarbons	< 1 %
Sulfur containing compounds (4-MMP, 3-MMP, 3-MH…)	< 0.1 %
Glycosidically bound aroma compounds	?

(Hopfen- vom Anbau bis zum Einsatz in Bier, Hans Carl Verlag)

What are Thiols?

- Thiols and Mercaptans are organosulfur compounds that contain a sulfur-hydrogen bond
- In form of aldehydes, ketones and esters: fruity and pleasant
- "Mercapto" relates to the ability to bind mercury (II) ions (capturing Mercury)
- Thermally unstable (?)
- Aromatic compounds with unique properties in wine, milk, cheese, vegetables, fruits…
  and HOPS!

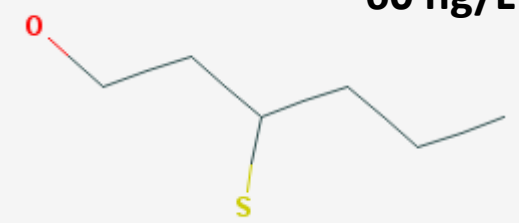
Important and Fruity Thiols

4 ng/L

4-Mercaptomethylpentan-2-one= **4MMP**=4S4M2Pone

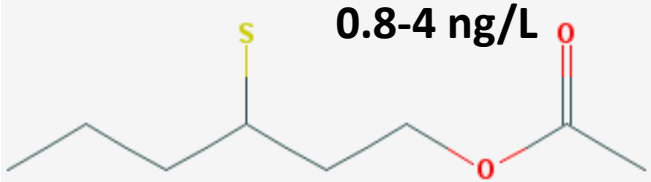


60 ng/L



3-Mercaptohexan-1-ol= **3MH** = 3SHol

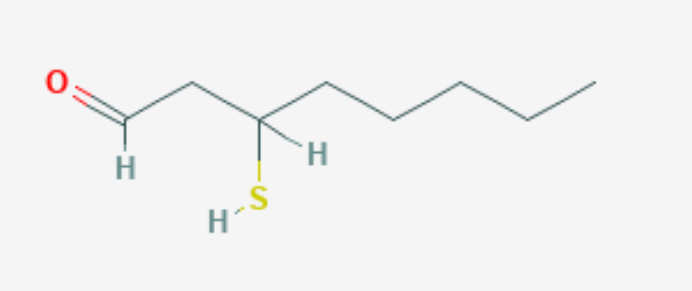

0.8-4 ng/L



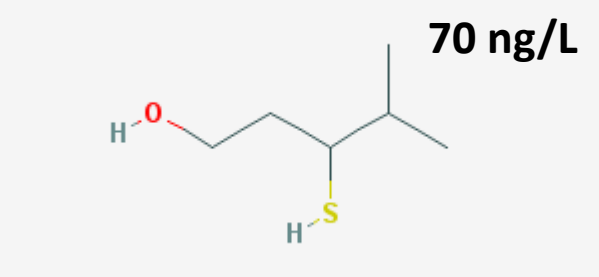
3-Mercaptohexylacetate = **3MHA**=3SHA




Important and Fruity Thiols



3-Mercapto-octanal**= 3MO** = 3SOal



3-Mercapto-4-methylpentan-1-ol=**3MMP**=3S4MPol

4-Mercapto-4-methylpentan-2-ol (4MMPOH) ?

box tree, cat pee

Range in wines (ng/L): 0-40

Odor threshold (ng/L) : 0.8

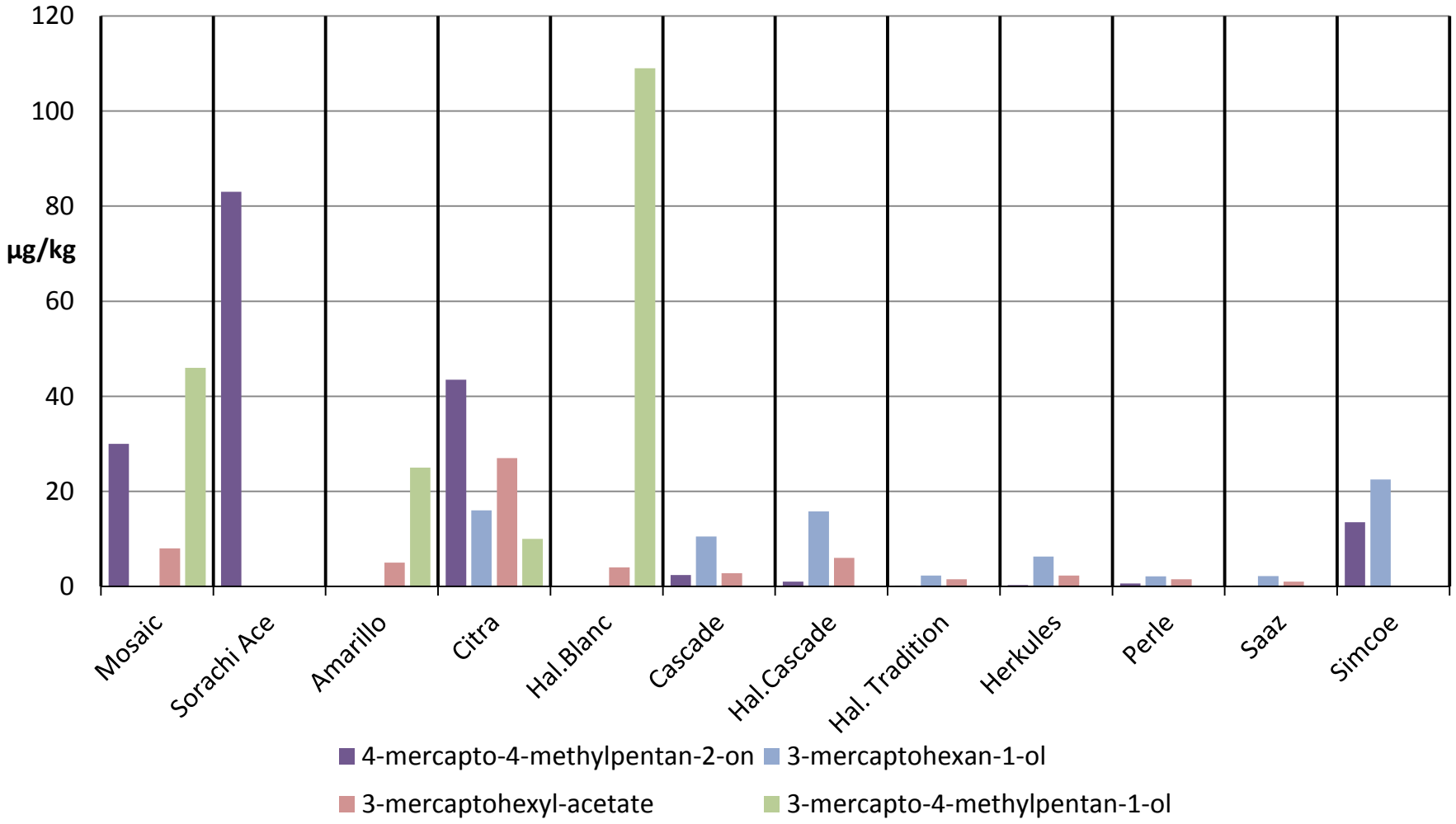
Found in Hallertau Blanc, Nelson Sauvin, Mosaic and Amarillo

4MMP – Recent Studies

- Flavour threshold as low as 1.5 ng/l
- In beers up to 150 ng/l (Dagan 2018)
- 4MMP concentrations in European and US cultivars from <1 to 114 µg/kg (Reglitz; Steinhaus 2017):
  - high in US varieties as Citra, Mosaic etc.
  - low in classic European varieties
- Stable concentration from cones to pellets
- Optimum extraction time for dry-hopping process is ~4 days
- Strong decline of 4MMP concentration with beer aging (Reglitz; Steinhaus 2018)

FREE THIOLS IN HOPS

Data from various studies of Collin et al and Dagan et al



SUMMARY ON THIOLS

- Different Thiols exhibit fruity flavours
- Thiols interact and change flavour quality
- Thiols can become unpleasant, depending on concentration, ratio, beer matrix, etc.
- Free Thiols in “New World Hops”
- Looking for the right hop variety will help to diversify
- Comprehensive data of all meaningful hop varieties is needed (incl. checking harvest dates)
- Behaviour during fermentation/dry hopping not fully understood

Agenda

- Diversification – relevant hop compounds
- Efficient dry hopping
- Provoak

Dry Hopping

- A crucial process step for the production of many (craft) beers
- Part of the most popular craft beer style recipes (IPA, Pale Ale, Hazy IPA…)
- Still a question mark for many brewers
- Hops as (the most?) important flavour contributor

Factors influencing Hop Aroma

variety
time of harvest
crop year, kilning

→ Point of addition
solubility/
evaporation

→ adsorption/
transformation/
interactions

→ dry hopping
(with/out yeast)
duration, temp,
agitation, etc.

aroma in hops → hoppy aroma in beer

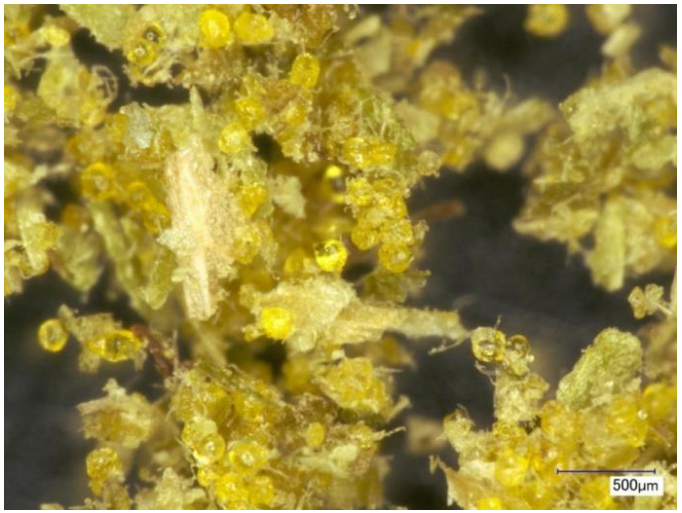
Harvest → Brewhouse → Fermentation → Lagering

plus…..filtration….bottling…storage

TECHNICAL BACKGROUND

Dry hopping highly depends on:

- Wettability and swelling properties
- Particle size and distribution
- Temperature
- Ethanol concentration
- Process type (static - dynamic)
- Contact time
- Oil concentration (variety, enrichment)
- Tank geometry and scale



Hop Varieties & Products

- All hop varieties and types can be used
- Hop Cones ("flowers"): contact area, oxygen
- Hop Pellets: homogeneous, better utilisation
- Hop Powder: difficult dosing
- Hop Oils/Emulsions: best yield, less beer losses; oil is insoluble => emulsion

Swelling of Hop cones/Pellets/Powder

Swelling properties depend on…

- Pelletization process
- Percentage of coarse fraction („green“ material)

Volume increase:

- Up to 1000%
- Severe beer losses without retention
- Key indicator for dry hopping equipment (hop bags, etc.)

Increase in Efficiency (Variety & Product)

In terms of varieties or products, dry hopping efficiency could be increased by:

- The usage of Hop Varieties with high oil contents (0.4-4 ml/100g)
- Enriched Hop Pellets (Type 45): reduce beer losses by up to 50%
- Hop oil products: excellent utilisation (up to 100%)
  => no beer losses at all

PHA Products

PHA Classics

Hop oil fractions

- Rose
- Myrcen
- Citrusy
- Sylvan
- Spicy
- Floral
- Herbal
- Custom Products

create a versatile flavour and aroma palate; often used as a mixture

PHA Varietals

From a specific hop variety → individual characteristics

- Hersbrucker
- Cascade
- Perle
- Mt. Hood
- Golding
- Tradition
- Other Varieties

late hopping character, strong taste impact

PHA Topnotes

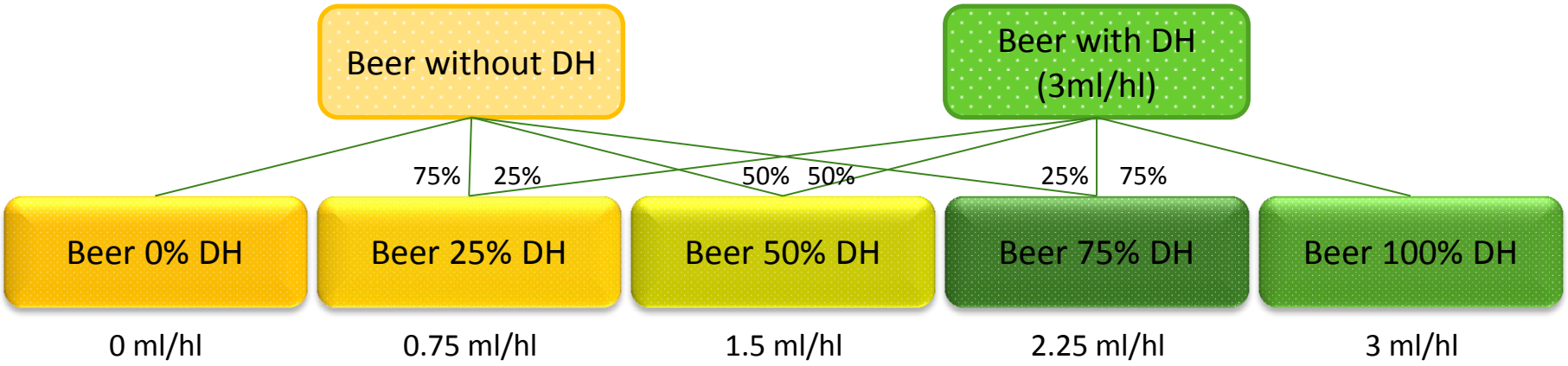
From a specific hop variety → individual characteristics

- Hersbrucker
- Cascade
- Perle
- Mt. Hood
- Golding
- Tradition
- Other Varieties

dry hopping character; highly volatile components of specific hop oil → more effect on aroma and less on taste

Substitution of Dry Hopping with PHA Products

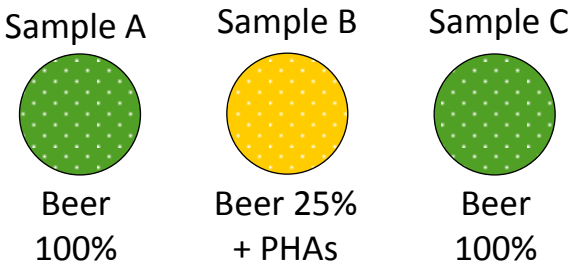
- Pale Ale as base beer
- Fermentation: Yeast WL001
- 25 IBU
- 2 beers: Cascade and Target
- Addition of PHAs to beers was 0%, 25%, 50% and 75%



Substitution of Dry Hopping with PHA Products

- Sensory evaluation of beers with 0%-75% PHAs against beer 100% (100% dry hopped with pellets)

  →Triangle tests, for example:



- Analysis of hop aroma compounds of selected beers (VLB) plus analyses of colour, total polyphenols and foam

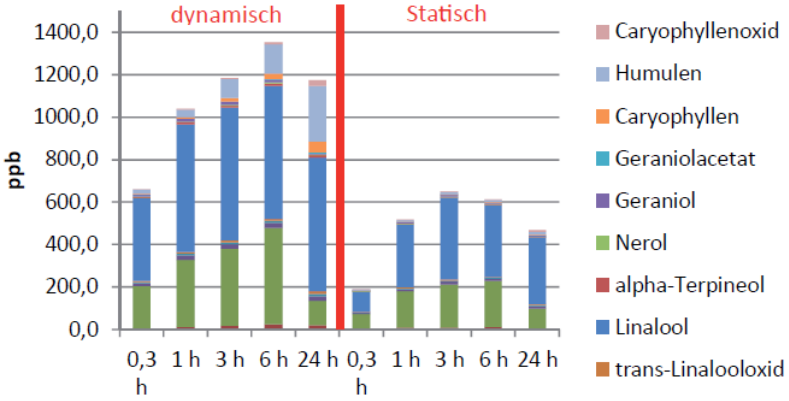
(Kerner, Master Thesis TUM, 2016)

Substitution of Dry Hopping with PHA Products

- It was possible to a certain degree to substitute hops used for dry hopping by adding PHA Topnotes (up to 75%)
- Depends on the beer style and the hop varieties used
- No influence on the colour or foam by the addition of PHAs
- Reduction of polyphenols
  → no polyphenols added by the use of PHAs
- Feasible for all traditional hops (including Cascade), but more challenging for dry hopping regimes with Citra/Mosaic or similar
- Trials are necessary for each beer to find the appropriated PHA combination and dose rate

Extraction during Dry Hopping: Static vs. Dynamic

- Static Extraction:
  - Diffusion only (Brownian Motion)
  - Slow and inefficient
    (decrease in concentration gradients:
    particle ↔ solvent)



- Dynamic Extraction:
  - Forced distribution through fluid and molecular dynamics
    (according to Fick's laws)
  - More efficient
    (higher concentration gradient over time: particle ↔ solvent)
  - Faster extraction of unwanted compounds (IBU, pH, Mouthfeel)

Layer Formation

- In tanks: layering will occur depending on aroma component and geometry
- For reproducible results, mixing or recirculation before filling is crucial

Process Technology - Time of Addition

Fermentation:

- CO_2 stripping of undesired aroma components
- Forced agitation during primary fermentation
- High temperatures – good solution of oils
- Biotransformation of aroma components
- Yeast cannot be reused
- Oxygen scavenging (yeast)
- Microbiological safety
- Higher ester formation
- Low ethanol in beginning (extraction/solubility!)
- Medium extraction yield

Process Technology - Time of Addition

Maturation (diacetyl rest / yeast harvested)

- Less CO_2 stripping / flotation
- Less agitation
- High temperatures
- Still active yeast present (oxygen!)
- Lower biotransformation
- Low ester formation
- Ethanol present (good extraction)
- High extraction yield

Process Technology - Time of Addition

Lagering:

- No CO2 stripping
- No agitation
- Low temperatures (after cool crash)
- No active yeast present
- Highest ethanol concentration
- Mostly operated with bypass equipment

Process Technology – Hops In

- Direct / Manual addition, loose or in bag or net
- Hop Slurry with DA water or beer (e. g. Rolec DryHopnik)
- CO_2 blow (e. g. Hop Cannon)
- Hop Percolation / Hop Bag (e. g. BrauKon HopGun, Torpedo)

Process Technology – Hops Out

- Standpipe, Racking arm (beer losses!)
- Sieving (Pipe Strainers)
- Centrifuge
- Decanter
- Pre-clarification with Candle Filter or Centrifugal Discharge Filter without filter aid
- Filtration with filter aids: (saturated) membrane and sheet filters better than Kieselguhr (?!)

Conclusions Dry Hopping

Parameters to look at in order to improve the dry hopping process:

- Choice of product (Raw Hops, Pellet Type, Extracts/Oils)
- Point of Addition
- Duration of Dry Hopping
- Special Equipment
- Oxygen Uptake
- Interactions like synergistic effects => trials & tastings

Consistent Hop Aroma?

- There are several possibilities for hop addition calculations
- There is no guarantee to get the same hop aroma in beer every time:
  - deviation in aroma of raw hops from year to year (crop to crop)
  - different hop growing regions and even hop gardens show different aroma of raw hops
  - even if the amount of dosed hop oils is the same: the composition of the hop oil might be different
  - there are interactions between hop oils and other beer compounds which may lead to variations of the aroma in the final beer
  - changes in the brewing process has an impact on the hop aroma in beer


BARTH-HAAS GROUP
PROVOAK
BREWERS' INSPIRATION

Background Barrel Aging

- Traditional method to increase aroma complexity of mostly wines and spirits
- For beer mostly pitched casks were used (except: Belgium, GB)
- Increasing popularity in craft brewing (Barley Wines, Dubbels, Ice-Bocks, Imperials)
- Aroma impact highly depends on type of wood, toasting, aging time and pre-usage

Background Barrel Aging

- Limited to some beer styles (high ABV and Color)
- Long maturation time (minimum 4-6 weeks, mostly several months)
- Barrels: cost intensive (Bourbon, Sherry, etc.)
- Hard to clean → microbiological hazards
- Single use for each beer style
- Product exposed to oxidation (Hop aroma!)
- High storage cost and know-how intensive

Solutions in Wine Industry:

- tank maturation with wooden staves, cubes, chips, powder

What is Provoak?

Project Target:

- Fresh, intense dry-hopping aroma combined with the pleasant body and mouthfeel of barrel aging

Development Scope:

- Easy-to-dose pelletized product
- Dual purpose product without downsides
- Cost and time efficient barrel aging character
- Suitable for late and dry-hopping
- Fits modern dry-hopping processes (dwell time)
- No limitation in ABV, Color or Beer Style

PROVOAK FACTS

Products:

- US Style (toasted) and EU Style (untoasted)

Dosage and dwell time:

- ~3 ml Oil per hl for around 7 days (if static)

Disclosure (patent pending):

- 100 % natural, food grade product, consisting of hops and wooden components.
- All hops produced got US and JP norms
- Not in conformity with German purity law
- Labeling: oak aged, oak flavoured, oaked, „auf Holz gelagert“

US Style & EU Style Character

OAK AGEING & HOP AROMA

DRY HOPPING PELLET

Complex and noble flavours with both hops and oak for innovative beers.

US-STYLE:
intense, sweet hop aroma - paired with
the typical heavy notes of toasted oak casks

red berries · dried fruit · bourbon
oranges · full-bodied · barrique
wild berries · vanilla

EU-STYLE:
fruity and light hop aroma - paired with
typical woody notes of untoasted oak casks

tangerines · wine-like · pineapples
oranges · tannic
grapes · oaky

APPLICATION:
similar handling compared to dry-hopping with hop pellets without the disadvantages of barrel ageing (oxidation, labor-intensive, costs)

DOSAGE:
provoak is dosed according to the hop oil concentration comparable to dry-hopping (3-6 mL Oil/hL)

CONTACT TIME:
approx. 1 week if dosed during lagering

DUAL PURPOSE PRODUCT:
one product - one pellet - one dose with
two aroma components: hops and oak

100 % NATURAL AND FOOD GRADE PRODUCT

PROVOAK MUNICH BROWN BEER AT BRAU 2018

PROVOAK

MUNICH BROWN

PROVOAK MUNICH BROWN BEER AT BRAU 2018

Comments from our Tasting at BRAU Beviale 2018:
strong woody flavour, combined with fruity and berry character:

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cherry, strawberry, dired fruit mango, guava, gooseberry, banana wood woody aromatic vegetal, citrusy Black currant oak, menthol jasmine, lily herbal, spicy smokey, woody woody, caramel herbal woody jamine tea, apricot srawberry menthol woody aromatic sweet fruits, woody aromatic woody aromatic, red berries liquorisch, barrel aged, malty woody, spicy, ripe orange liquorice, cassis, woody sweet, smokey orange, green pepper, raspberry woody woody honey, grapefruit sweet fruits, tobacco, woody sl woody, citrus okay, toasty woody, caramel, berry woody, raspberry spicy herbal woody cream caramel quince, peach honey, lemon, juniper red berries, sweet fruits honey, sweet fruits, oak woody, sweet, fruit woody, sweet fruit, leather herbal, caramel red berries blueberry, tobacco cassis tangerine, honey, peach red berries, sweet fruits herbal, spicy, cream caramel caramel, herbal woody, smoky menthol, green grassy, red berries cassis, woody woody, smoky, caramel Cognac, barrique, leather honey, aromatic, woody woody, red berries jasmine, oak, tobacco woody juniper smoke woody, spicy, herbal woody coffee, smokey sweet fruits tropical fruits, grape, woody woody woody, vegetal woody aromatic, cream caramel woody aweet fruits, grassy ginger, fennel, artichoke barrique, lychee, plum, vanilla berries woody, fruity smokey, cherry, vanilla red berries

Thanks to…

…all the ambitious researchers,

…all passionate brewers in love with hops

…our Brewing Solutions Team!

We help you to find the Hop aroma you are looking for!

Contact us via

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