Because not every beer is Stone Enjoy by IPA



Preserving Hop Aroma



The Plan

- > Hop oils and odor compounds.
- > How they end up in beer.
- > Ear to the ground: ongoing research.
- > Aroma survival guide.



In case there's a vocabulary test

Landrace hops

New World hops

Aroma threshold

Anosmia

Synergy

Masking

Biotransformation





Source: "125th Anniversary Review: The Role of Hops in Brewing," J I Brewing



Compounds, the short list

myrcene caryophyllene humulene farnesene linalool geraniol citronellol nerol pinene 3-mercaptohexan-1-ol (3MH)

4-mercapto-4-methylpentan-2-one (4MMP)

green, resinous, piney woody woody, piney floral floral, orange floral, rose, geranium citrusy, fruity rose, citrusy spicy, piney black currant, muscat black currant, tropical



Esters/Acetates	Monoterpenoids	Sesquiterpenoids	Ketones	
2-methylbutyl propanoate (1)	Monoterpene hydrocarbons	Sesquiterpene hydrocarbons	2-nonanone (31)	
3-methylbutyl propanoate (2)	β-myrcene (14)	β-caryophyllene (38)	5-undec-2-one (32)	
3-methylbutyl 2-methylpropanoate (3)	β-phellandrene (15)	α-humulene (39)	2-undecanone (33)	
2-methylbutyl 2-methylpropanoate (4)	limonene (16)			
cis-2-pentenyl butanoate (5)	cis-β-ocimene (17)	Oxygenated sesquiterpenoids	Miscellaneous	
2-methylbutyl butanoate (6)	y-terpinene (18)	caryophyllenyl alcohol (40)	hexahydro-1,1-dimethyl-4-m	ethylene-4H-
2-methylbutyl 2-methylbutanoate (7)	terpinolene (19)	humulene epoxide I (41)	cyclopentafuran (34)	
cis-3-hexenyl isobutanoate (8)		humulol (42)	3,4-dimethyl-2,4,6-octatriene	e (35)
2-methylbutyl 3-methylbutanoaat (9)	Oxygenated monoterpenoids	humulene epoxide II (43)	2,2-dimethyl-4,5-dipropenyl-	1,3-dioxolane (36)
methyl octanoate (10)	linalool (20)	humulene epoxide III (44)	β-damascenone (37)	
octyl acetate (11)	borneol (21)			
heptyl 2-methylpropanoate+isopentyl hexanoate (12)	p-menth-1-en-4-ol (22)	ř.		
methyl trans-4-decenoate (13)	citral (23)			
	a-terpineol (24)	ОН	\frown	ОН
	nerol (25)	<		2
	geraniol (26)	1 1	Сон сон	i.
(13) (3)	methyl geranate (27)	\sim	\sim \times	
		(29)	(24)	(26)
	Hop oil-derived monoterpenoids	ОН		
0	(not originally present in hop oil)			
$\sim \sim $	myrcenol (28)	(25)	(20)	
(10)	citronellol (29)			
	terpinyl ethyl ether (30)			lable 1

Source: "Characterisation of Fresh and Aged Singled Hop Beers," Filip Van Opstalaele, et al.





Figure 3. Comparison of monoterpene alcohol compositions in various hops: 2007 crop (HHT_1, HHM, Variety A, Variety B, Pacifica, NNS, Cascade_1, Citra, Millennium and Nugget); 2008 crop (Amarillo, Apollo, Bravo, Cascade_2, Chinook, HBC369, Glacier, Mt. Hood, Palisade, Simcoe and Willamette); 2009 crop (HHT_2 and SSA).

Source: "Analysis of Hop-Derived Compounds in the U.S. Hops," Kiyoshi Takoi, et al.

Halltertau Tradition 1 & 2, Magnum, Saaz, Var A, Var B, Pacifica, Nelson Sauvin, Amarillo, Apollo, Bravo, Cascade 1 & 2, Chinook, Citra, Glacier, Mosaic, Millennium, Mt. Hood, Nugget, Palisade, Simcoe, Willamette.



4-methyl-4-mercapto-2-pentanone (4-MMP)

- Citra
- Cascade
- Chinook
- Simcoe
- Summit
- Apollo
- Topaz
- Cluster
- Mosaic





0810

Black currant Ribes Tom-cat urine





J.S. Ford of the Wm. Younger & Co.'s Brewery in Edinburgh, Scotland :

-Physical examination "pronounced, unpleasant nose."
-In the dry hop tests at 4 ounces per barrel, "too bitter, rank and slightly unpleasant."

Another opinion:

"It (the American hop) is rather a stronger bitter than the European hop, and with a stronger scented flavor in many cases."





Hallertau Mittelfrüh

Bergamot Liquorice Blackberry Aniseed Citrus fruits



Hallertauer Mittelfrüh (cold infusion*)

Hallertauer Mittelfrüh (raw hops)

Source: Hop Aroma Compendium, Joh. Barth & Sohn





Source: Hop Aroma Compendium, Joh. Barth & Sohn



Crystal

Descriptor	This includes the following aromas:	
Menthol	Mint, melissa, sage, metallic, camphor	
Теа	Green tea, camomile tea, black tea	
Green fruits	Pear, quince, apple, gooseberry, wine yeast, ethereal	
Citrus	Grapefruit, orange, lime, lemon, bergamot, lemon grass, ginger	
Green	Green-grassy, tomato leaves, green peppers	
Vegetal	Celeriac, leek, onion, artichoke, garlic, wild garlic	
Cream caramel	Butter, chocolate, yoghurt, gingerbread, honey, cream, caramel, toffee, coffee	b
Woody aromatic	Tobacco, cognac, barrique, hay, leather, tonka, woodruff, incense, myrrh, resin	
Spicy/herbal	Lovage, pepper, chilli, curry, juniper, marjoram, tarragon, dill, lavender, aniseed, liquorice, fennel	
Red berries	Cassis, blueberries, raspberries, blackberries, strawberries	
Sweet fruits	Banana, watermelon, honeydew melon, peach, apricot, passion fruit, lychee, dried fruit, plum, pineapple, white jelly bears	
Floral	Elderflower, camomile blossom, lily of the valley, jasmine, apple blossom, rose, geranium	



Source: Hop Aroma Compendium, Joh. Barth & Sohn



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First wort hopping is not an aroma addition

Brewery A

Moved last addition (Tettanager & Saazer type) to first wort – 34% of total addition.

	Traditional	First Wort
OG	11.6	12
ABV	4.8%	5.1%
IBU	38	40
Linalool	29 ug/l	8.1
Geraniol	18.8	10.7
Humulene	32.7	19.6
Epoxides		

Brewery B

Moved last addition (Tettanager) to first wort – 53% of total addition.

	Traditional	First Wort
OG	12	11.9
ABV	4.8%	4.7%
IBU	27	33
Linalool	34.1	6.4
Geraniol	14.6	13.7
Humulene	10.8	9.8
Epoxides		





Source: "Hop-Derived Odorants Contributing to Aroma Characteristics of Beer," Toru Kishimoto







SUNTORY

The influence of late-hopping temperature on the organoleptic profiles of beer



Source: "Study on the Attractive Aroma for Beer," Takako Inui













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Rock Bottom experiment

• Longer post-boil residence (80 minutes vs. 50) resulted in more hop flavor, aroma, and perceived bitterness than shorter. "This is in contrast to a commonly voiced opinion among craft brewers that volatile hop oils are quickly driven out of hot wort, and therefore, wort cooling should happen as quickly as possible after the addition of final hops at or near the end of the boil to preserve the hop flavor and aroma in the wort."

- Longer post-boil residence resulted in more hop flavor than dry hopping, and that hop flavor is best developed in the kettle.
- A combination of late hopping and dry hopping resulted in greater hop aroma than longer late hopping. However, it appeared there was a diminishing return for additional quantities used in dry hopping.





Aldehydes were observed to increase with ageing time.

After 6 months, Strecker aldehydes and furfural levels were much higher for the DH beers, with the exception of hop variety C.

Beer C-LH showed a significantly higher increase than beer C-DH.

The lipid oxidation aldehydes on the other hand, did not exhibit this trend, although C-LH did show a modest increase.

Source: "Analytics and Sensory Assessment of the Flavour Stability of Dry-hopping in Single-hop Beers," Yvan Borremans, et. al.







All the fresh beers showed negligible ageing effects. The sensory difference between the LH and DH beers became very clear after 6 months , with the DH beers receiving higher scores than the LH beers, at least for hop variety A and B. In contrast, C-DH was more stable than C-LH. For all three hop varieties, the panel's personal preference between the 6 month old beers coincided with the lowest value of OAS.

Source: "Analytics and Sensory Assessment of the Flavour Stability of Dry-hopping in Single-hop Beers," Yvan Borremans, et. al.





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Preliminary brewing: Cascade



- Typical harvest hops = apple, apricot/peach, and sweaty/onion/garlic notes.
- Late harvest hops = higher melon and floral notes.

Source: "Hop-related brewing research at Oregon State University, "Thomas Shellmammer and Daniel Sharp



More research: Thiols and refermentation



Source: "Flavour profile of refermented beers," Jacques Gross, et al.



Still more research

At Kirin: Non dried, freshly frozen hops. Hops frozen soon after picking.

"Frozen hops impart fresh and pure flowery aroma. Content of linalool along with other terpene alcohols was high, and terpene oxides were low, possibly due to non-heat treatment."

At Kirin: Dip Hopping. Hops added to fermentation tank. Dip hopped beer high in linalool and low in myrcene compared to dry hopped beer. "We assume that high linalool was due to low temperature extraction, and low myrcene was due to elimination by yeast."

In Germany: On variations between types of PET bottles. An IPA and a pilsner (both beers were dry hopped) were compared as they were aged in different PET bottles, A (Coated Monolayer) and B (Monolayer).





Source: "Flavour and hop aroma stability of craft beers packed in different PET bottles," Roland Folz, et al.





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Chinook



Source: Sierra Nevada Brewing Company



Aroma survival guide

- Store you hops and your beer cold, your hops colder.
- ➢ Beware the skunk.
- Look beyond the hop variety.
- Remember the role of yeast in both fermentation and biotransformation.
- Ongoing research will reveal more about the importance of strains in the latter.
- Do not accept a Facebook friend request from oxygen.
- Use hydrophillic correctly in a sentence.
- ➢ Use the phrase "conflictual art" at least once at every homebrew meeting you attend.
- > Drink it now. Those guys from Stone might be on to something.
- "Deliver" your own beer whenever possible.



Humulene



Source: Sierra Nevada Brewing Company

