

The Science of Brewing:

How 4 simple ingredients become the best beverage in the world

Part 2: Hops

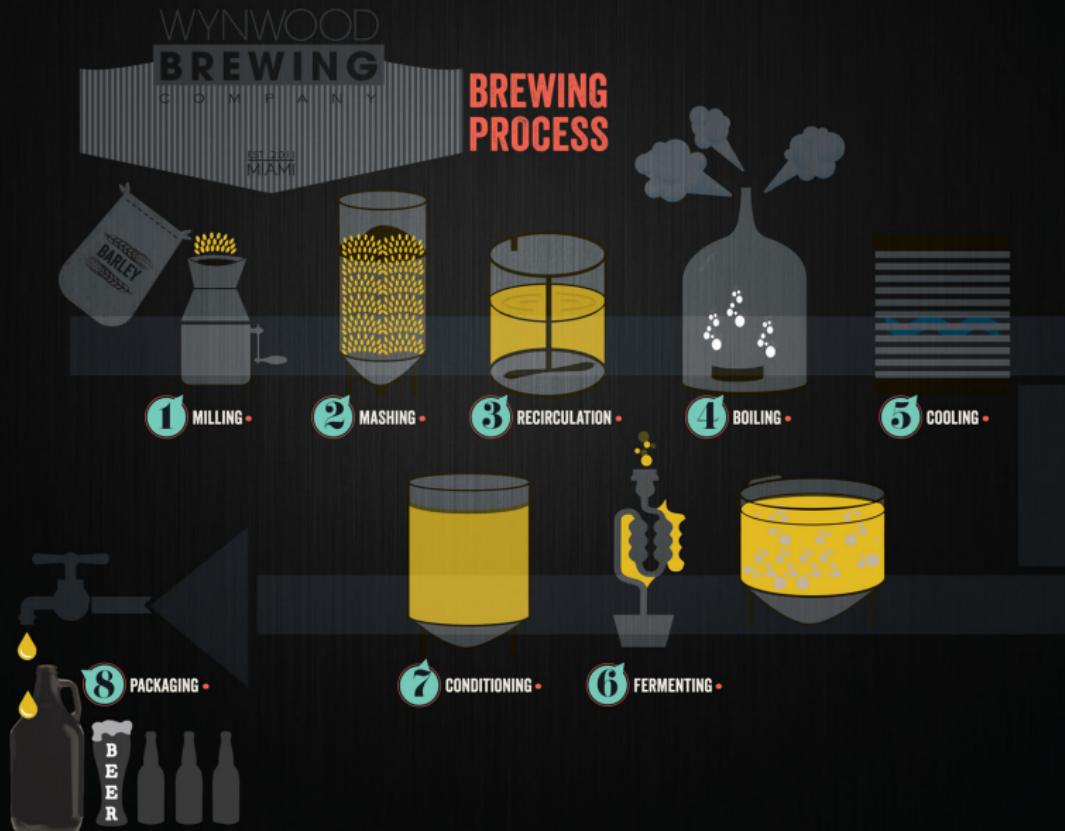
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Ingredients

- ① Barley
- ② Hops
- ③ Water
- ④ Yeast



Disclaimer

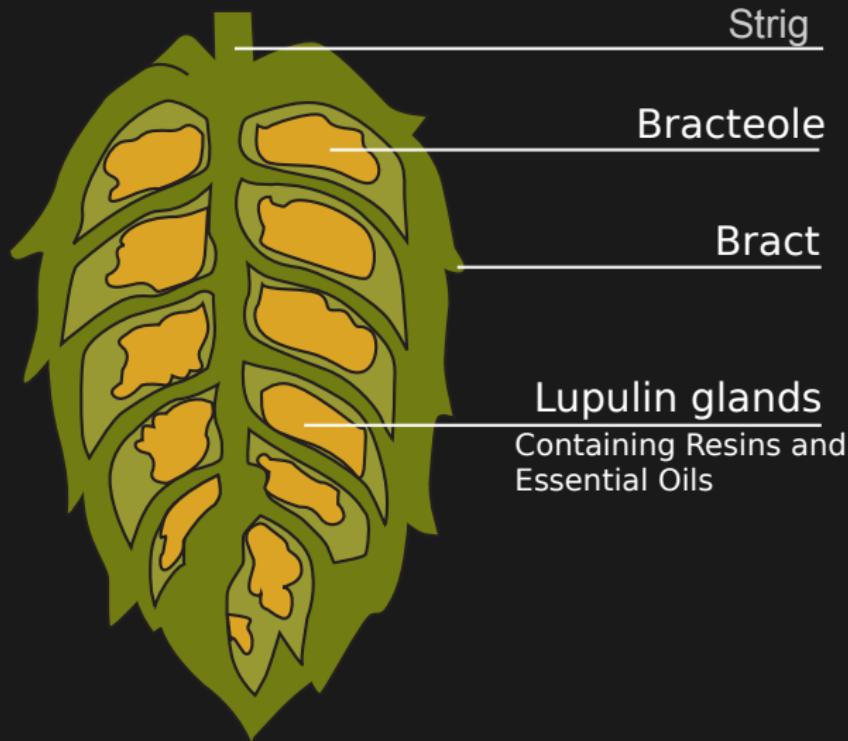
- ① I am not an expert

Hops

- *Humulus lupulus*
- flower, cone, strobilus



Hops



History of Hop Cultivation

- Documented cultivation between 736–1079 in Hallertau, Germany
- Pepin the Short left hop gardens to Charlemagne in 768
- Hopped beer introduced to Britain in 1400
- Hops cultivated in England 1524
- Hops cultivated in America 1629



Modern Cultivation

- Dioecious: males not used for brewing
- Bines trained over strings on trestles
- Susceptible to mold and mildew



Unhopped beer

- Yeast never 100% effective; beer is sweet
- Gruit: bitter spice mixture: sweet gale, mugwort, yarrow, ground ivy, horehound, and Calluna heather, juniper berries, ginger, caraway seed, aniseed, nutmeg, cinnamon, etc.
- More expensive, more prone to spoilage



<http://www.gruit.es/en/brewmaster-1a-part/>

Hopped beer

- Cheap
- Antibacterial properties
- Tasty!

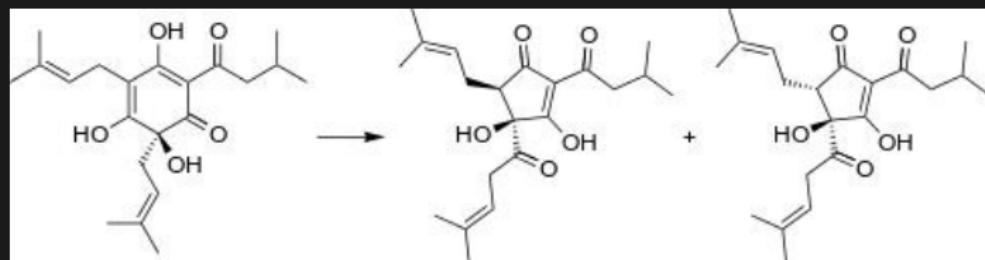


Hops are:

Components	(%w/w)
Cellulose + lignin	40.0 – 50.0
Protein	15.0
α acids	2.0 – 17.0
β acids	2.0 – 10.0
Minerals	8.0
Polyphenols and tannins	3.0 – 6.0
Lipids and fatty acids	1.0 – 5.0
Hop oil	0.5 – 3.0
Monosaccharides	2.0
Pectin	2.0

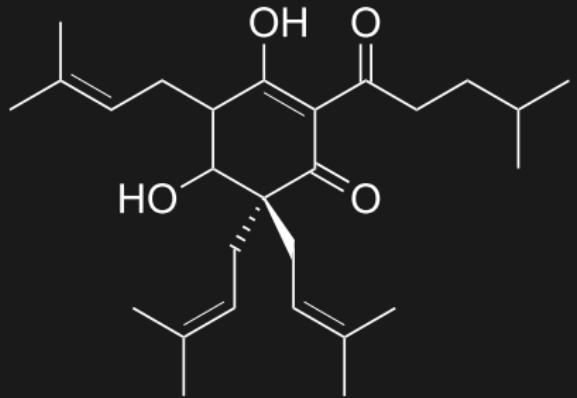
European Brewery Convention Hops and Hop Products, Manual of Good Practice; Getranke - Fachverlag Hans Carl: Nurnberg, Germany, 1997. Water not shown

α acids (Humulones)



- Bitter (IBU measuring)
- Antimicrobial
- “skunking”: sun + isohumulones → free radicals → thiols
- Good bitterness

β acids (Lupulones)



- Bad bitterness

Essential Oils

Myrcene

- Thyme, cannabis, lemongrass, bay leaf, mango, lavender
- Aromatic, but unstable; prone to Diels-Alder reactions



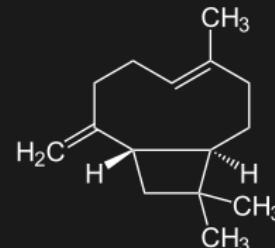
Humulene

- Ginger, cannabis, orange, pine, sage, tobacco
- Lends aroma; especially high percentage in Noble hops



Caryophyllene

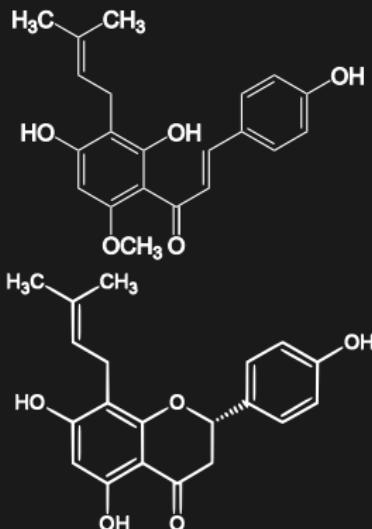
- Black pepper, cannabis, caraway, cloves, oregano, rosemary



Flavenoids

Xanthohumol

- Ends up about about 2 g/L – 1.2 mg/L
 - most abundant flavenoid in hops
 - Contributes bitterness and flavor
- 8-Prenylnaringenin phytoestrogen



International Bittering Units

IBUs: isomerized α acid content

Beer style	IBUs
Lambic	0-10
Wheat beer	8-18
American lager	8-26
Pilsner	24-44
Porter	18-50
Pale ale	30-50
Stout	30-90
Barleywine	34-120
India pale ale	40-120

How to hop

Time	Type	Purpose
30-90	bitterness	conversion of α acids
10-30	flavour	extraction of oils and other volatile compounds
0-10	aroma	extraction of delicate, volatile compounds
...	dry	slow extraction of oils and other compounds

Notable Hops

Noble Hops

- The OG cultivars: Hallertau, Tettnanger, Spalt, and Saaz
- Pilsen Urquell, Stella Artois

British Noble Hops

- Fuggle, East Kent Goldings and Goldings
- Guineess, Smithwicks

New World Hops

- Cascade, Chinook, Nugget, Citra, Simcoe, Willamette
- IPAs

Pacific Hops

- Nelson Sauvin, Pacifica, Pacific Gem, Super Alpha

- <http://onlinelibrary.wiley.com/doi/10.1002/jib.160/pdf>
- http://www.uvm.edu/extension/cropsoil/wp-content/uploads/2014HopsConference_Shellhammer_brewersperspective.pdf
- wikipedia (lots of wikipedia)

IPA Recipe

Malt

- 5kg Irish Pale Malt (4-6)
- 500g Carapils (5)
- 500g Cara Red (20)

Yeast

- Northwest Ale Yeast

Mash for 60 minutes at 65°. Hot crash/sparge with 8 liters at 75°.

Boil 70 minutes. Target gravity: 1.065.

Hop Additions:

- 60mins 50g Eureka
- 45mins 50g Eureka
- 30mins 25g Chinook
- 20mins 25g Mosaic
- 10mins 25g Chinook
- 5mins 25g Mosaic
- flameout 25g Chinook, 50g Mosaic
- (...25g Cascade, 25g Chinook)