

# Beer flavor & Nature and origin of defects



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## The key drivers of beer flavor

Malt

Hops

- Bitterness – iso alpha acids
- Aroma – hop oil

Fermentation

- Ethanol
- Esters
- Higher alcohols

Defects



## Chemical Composition of Hops

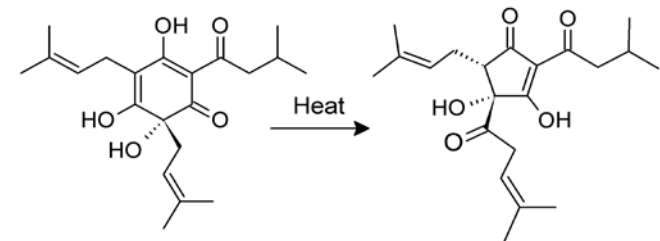
| Principle Components    | Concentration (%w/w) |
|-------------------------|----------------------|
| Cellulose-lignins       | 40.0 - 50.0          |
| Protein                 | 15.0                 |
| Alpha acids             | 2.0 - 17.0           |
| Beta acids              | 2.0 - 10.0           |
| Water                   | 8.0 - 12.0           |
| 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                  |
| Pectins                 | 2.0                  |
| Amino acids             | 0.1                  |



European Brewery Convention *Hops and Hop Products, Manual of Good Practice*; Getränke - Fachverlag Hans Carl: Nurnberg, Germany, 1997.



## Iso-alpha acids are the most important contributors to bitterness in beer



Alpha acid: Humulone  
Low solubility  
Low bitterness

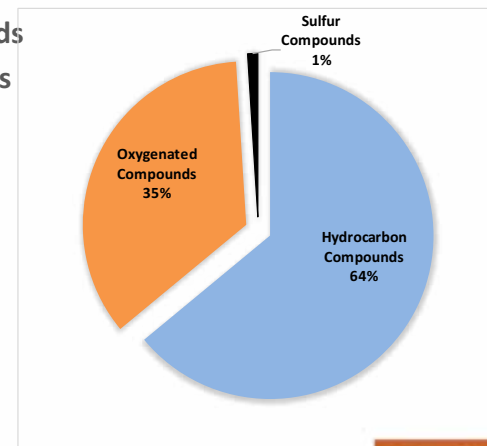
Iso-alpha acid: isohumulone  
High solubility  
High bitterness



# Hop oil composition

## What classes of compounds make up hop oil?

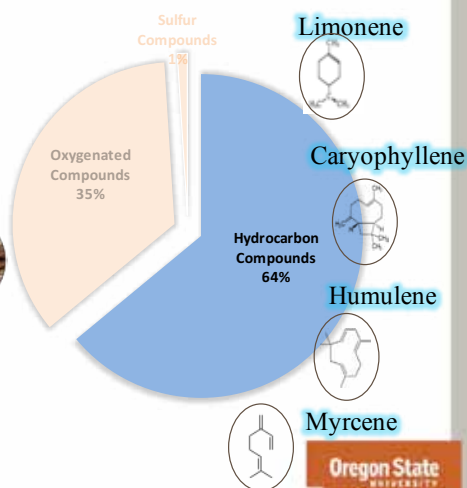
- Hydrocarbon Compounds
- Oxygenated Compounds
- Sulfur Compounds



## Three groups of compounds

### Hydrocarbon Compounds

- Myrcene
- Humulene
- Caryophyllene
- Limonene



Limonene

Caryophyllene

Humulene

Myrcene

## Three groups of compounds

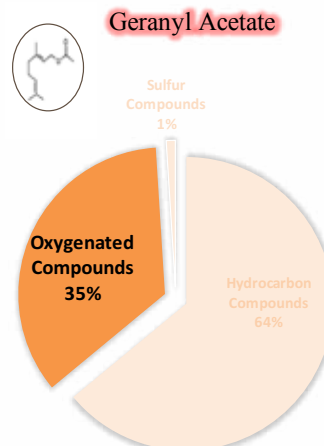
### Oxygenated Compounds

- Linalool
- Geraniol
- Citronellol
- Geranyl Acetate



Geraniol

Linalool



## Three groups of compounds

### Sulfur Compounds

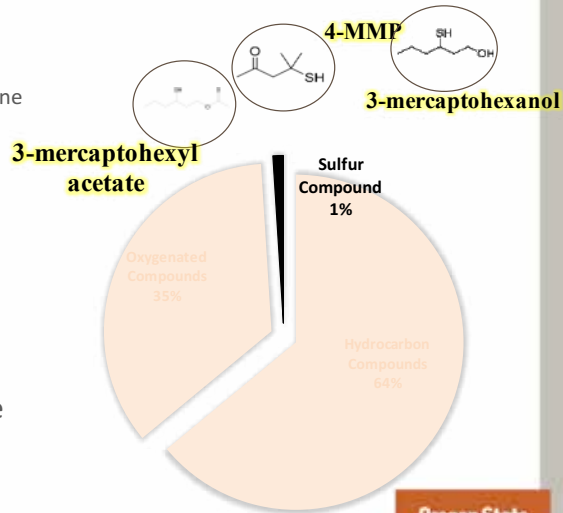
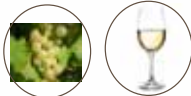
- 4-mercapto-4-methyl-pentan-2-one



- 3-mercaptohexanol

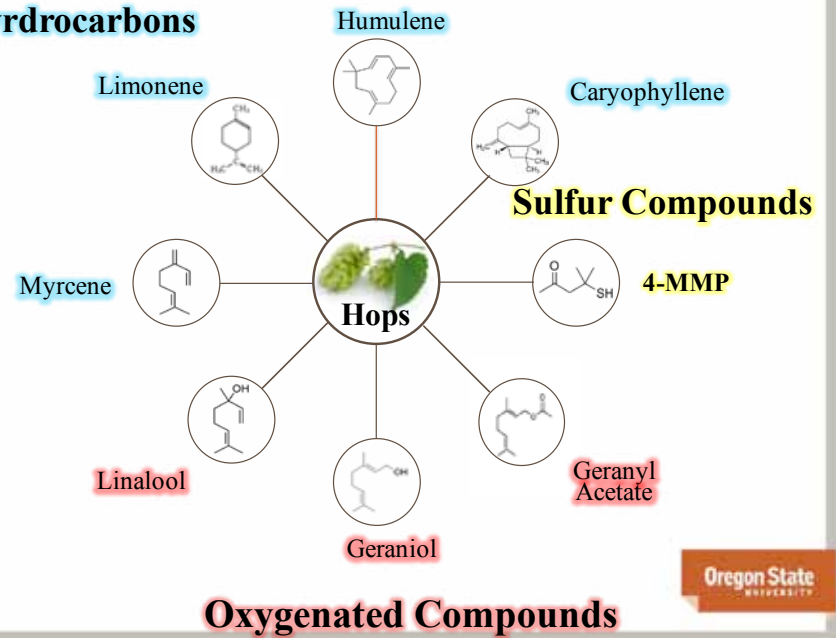


- 3-mercaptohexyl acetate



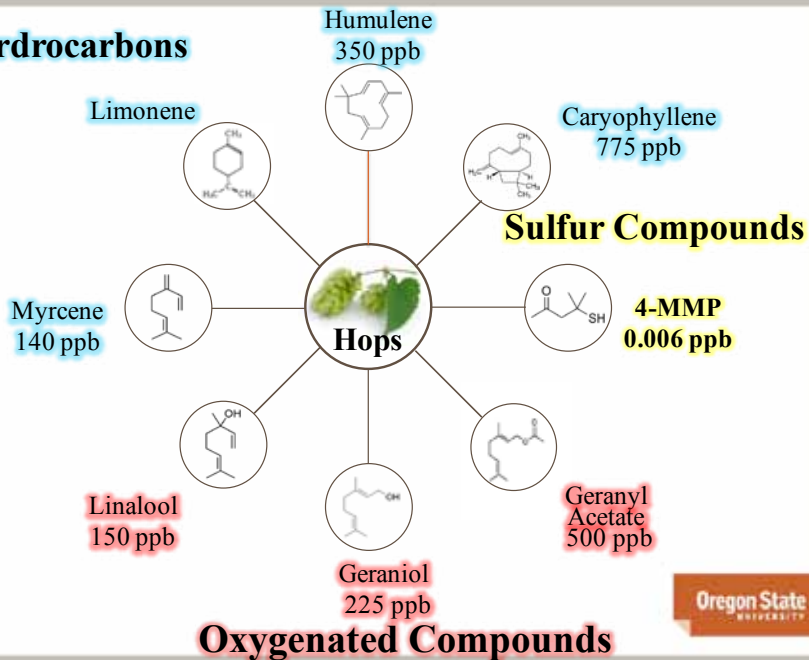
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### Hydrocarbons



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### Hydrocarbons



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### Defects and Off Flavors

- Dimethyl sulfide
- Diacetyl
- Acetaldehyde
- Ethyl acetate
- Banana/Clove
- Acetic
- Medicinal
- Oxidized
- Lightstruck

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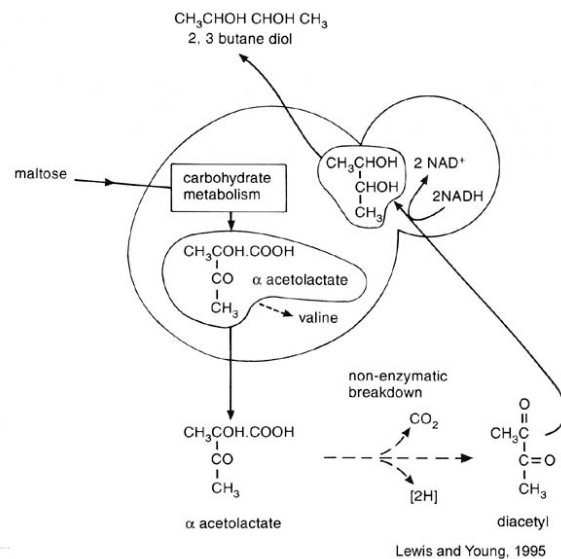
## Dimethyl Sulfide (DMS)

- Malt derived
- S-methyl methionine is precursor
- SMM converted to DMS with high heat
- DMS is volatile
- Wort boiling, hot wort holding, fermentation temperature, yeast type
- Bacterial contamination by Enterobacteria

## Diacetyl

- Yeast metabolism byproduct
- $\alpha$ -acetolactate leaks from cell
- Oxidized extracellularly to diacetyl
  - Very low aroma threshold (50 – 30 ppb)
- Diacetyl taken up by cell and reduced to
  - Acetoin and then on to 2,3 butanediol
  - Much higher aroma threshold
- Rate limiting step is oxidation
  - Higher temperatures will speed this up
- Bacterial contamination - *Pediococcus*

## Diacetyl formation and breakdown



## Acetaldehyde

- By-product of fermentation
- Can be produced by *Zymomonas* (post fermentation)
- Drivers for Acetaldehyde
  - Poor yeast management
  - High O<sub>2</sub> levels at packaging
  - Short maturation time
  - Pressurized brewing

## Ethyl Acetate

The main ester produced during fermentation

Typically found at or below threshold levels (20 ppm)

Can be produced by wild yeast

## Banana/Clove

Banana (isoamyl acetate)

Esterase activity of the yeast is strain dependent

Phenolic level and type (clove versus smoky) is yeast strain dependent

POF+ gene

Ferulic acid in malt/wheat leads to 4-vinyl guaiacol in beer

Wild yeast

Bavarian weizen yeast

## Acetic

Bacterial contamination – *Acetobacter*

Wild yeast infection - *Brettanomyces*

## Medicinal

4-vinyl phenol

*Brettanomyces* and other POF+ yeast

Chlorophenol (Band-Aid aroma)

Residual levels of chlorine following cleaning/sanitation

## Phenolic off flavors from wild yeast

| Compound         | Descriptor   |
|------------------|--|
| 4-ethyl guaiacol | Spicy, Smoky, Bacon, Phenolic, Clove                     |
| 4-vinyl guaiacol | Spicy, Clove, Smoky, Phenolic, Pepper, Woody             |
| 4-ethyl phenol   | Phenolic, Smoke, Bacon and Ham                           |
| 4-vinyl phenol   | Chemical, phenolic, medicinal with sweet musty and meaty |

## Infected fermentations/beer

Most common bacterial infection involve...

Lactic acid bacteria (LAB)

*Lactobacillus* (species)

Sour (lactic acid), occasional diacetyl, silky turbidity

Viscous, 'ropy' in some cases

*Pediococcus damnosus*

Diacetyl

LAB grow quickly, but are sensitive to hop acids

Wild yeast, *Brettanomyces*, grow slowly

## Flavors from microbial activity

| Descriptor           | Compound         | Microorganism  |
|----------------------|------------------|--|
| Green apple          | Acetaldehyde     | <i>Zymomonas</i>   |
| Apples               | Ethyl hexanoate  | Yeast  |
| Goaty, Sweaty        | Caproic acid     | Yeast, <i>Megasphaera</i>  |
| Banana               | Isoamyl alcohol  | Brewing Yeast  |
| Fruity, Solvent      | Ethyl acetate    | Brewing Yeast  |
| Butter, Butterscotch | Diacetyl         | Yeast, <i>Lactobacillus</i> , <i>Pediococcus</i>                 |
| Honey                | 2,3 pentanedione | <i>Lactobacillus</i> , <i>Pediococcus</i>                        |
| Clove                | 4-vinyl guaiacol | POF+ Yeast   |
| Medicinal            | 4-ethyl phenol   | <i>Brettanomyces</i>   |
| Creamed corn         | Dimethyl sulfide | <i>Enterobacteriaceae</i>  |
| Rotten eggs          | Hydrogen sulfide | <i>Enterobacteriaceae</i> , <i>Pectinatus</i> , <i>Zymomonas</i> |
| Vinegar              | Acetic acid      | <i>Acetobacter</i> , oxidative yeast                             |
| Sour                 | Lactic acid      | <i>Lactobacillus</i> , <i>Pediococcus</i>                        |

## Lightstruck

3-methyl-2-butene thiol - 8 ppt threshold

UV light + sensitizer (riboflavin) + iso  $\alpha$  acid

Reaction with sulfur compounds produces thiol

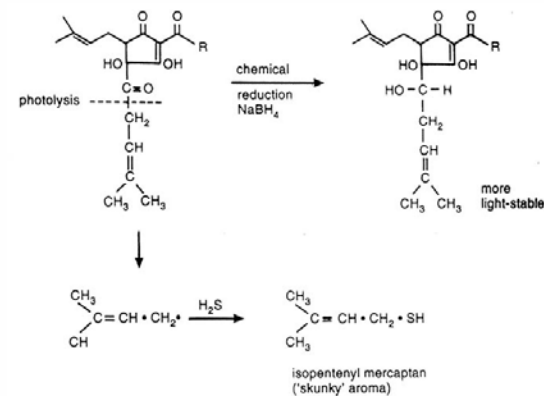


Figure 9.4 Photo-oxidation of hop constituents leading to sun-struck aroma.

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ALL THINGS  
BEER

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