Post-Harvest Hop Quality

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Yakima, Washington USA
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1. Primary factors influencing post-harvest hop quality.
2. Oxidation: Causes and effects.
3. Controlling oxidation.
4. Hop quality parameters and brewers’ expectations.
Enemies of Hop Quality

1. Time

2. Temperature

3. Oxygen

The primary culprit effecting dried hop quality after harvest is oxidation of bitter and aroma compounds.

Old terminology

- Soft resins
- Hard resins
What Happens with Oxidation?

Diminished brewing value

- Loss of bitterness potential
- Changes/degradation of hop aroma

Oxidized alpha acids will not isomerize during the brewing process and therefore do not contribute to beer bitterness.

- Less important factor with aroma hops, but bitterness is affected nonetheless.

Beta-acids - not a contributor to beer bitterness but will form humulones when oxidized. These contribute an less favorable bitterness to beer.
Specific Oxidation Effects on Hop Aroma

Oxidation of hop aroma compounds, primarily the essential oils of hops, occur at a rate similar to that of the hop bitter acids.

Typical hop aromas, including floral, herbal, spicy, fruity and citrus, can be transformed nasty compounds exhibiting sweaty, cheesy, and other unfavorable aromas.

However, some oxidation is good – contributing to the herbal/spicy notes defining “noble” hop aroma.
Hop Aging Starts at Harvest

As soon as a hop plant is removed from the hill, the clock starts ticking.

Hops, like beer, do not improve with age.

Choices:

• Pick hops and use for fresh-hop ale within 18-24 hours.
• Freeze hops for later addition to fresh-hop ale.
• Dry hops for storage and/or further processing.

Properly dried hops will keep from spoiling, but oxidation reactions will still occur.
Kilning and Baling

Kilning is the standard method for drying commercial hops.

Protects from spoilage, but both heat and time contribute to:

- Evaporation of volatile hop essential oils
- Oxidation of the hop compounds

Important aspects of hop kilning

- Temperature
- Time
- Air flow
- Hops should be dried to a moisture content of 8 to 10%
  - Too much moisture will contribute to spoilage and mold growth.
  - Over-drying drives off volatile aromas compounds, causes the cones to shatter upon handling; creates potential for spontaneous combustion.
Spontaneous Combustion

Dried hops immediately following harvest are susceptible to spontaneous combustion.

Mistakenly thought to be a risk factor for high-alpha bittering varieties, but a primary contributor is a hop variety’s propensity for oxidation.
Hop Storage Stability

Hop storage stability is related to rate of oxidation.

Hops vary widely in their stability.

Storage stability is determined by measuring the loss of alpha-acids after a set standard temperature and time.

e.g. 20 deg C for 6 months.
Hop Variety Storage Stability

Cascade
U.S. Aroma Hop

Cascade was developed in the U.S.D.A. breeding program in Oregon and released as a U.S. aroma variety in 1972. It is characterized by a dark green elongated cone with an aroma that is of medium strength with very distinct floral notes and is often described as having grapefruit-like character. Cascade is the definitive hop for American craft brews.

<table>
<thead>
<tr>
<th>Pedigree</th>
<th>Cross of English Fuggle with male originating from Russian variety Serebrianka</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aroma</td>
<td>Unique floral, citrus</td>
</tr>
<tr>
<td>Alpha Acids*</td>
<td>4.5 - 7.0 %</td>
</tr>
<tr>
<td>Beta Acids</td>
<td>4.8 - 7.0 %</td>
</tr>
<tr>
<td>Cohumulone</td>
<td>33 - 40 % of alpha acids</td>
</tr>
<tr>
<td>Total Oil</td>
<td>0.7 - 1.4 ml/100g</td>
</tr>
<tr>
<td>Myrcene</td>
<td>45 - 60 % of total oil</td>
</tr>
<tr>
<td>Humulene</td>
<td>8 - 13 % of total oil</td>
</tr>
<tr>
<td>Caryophyllene</td>
<td>3 - 6 % of total oil</td>
</tr>
<tr>
<td>Farnesene</td>
<td>3 - 7 % of total oil</td>
</tr>
<tr>
<td>Storage Stability</td>
<td>Very poor</td>
</tr>
</tbody>
</table>

Citra™
U.S. Aroma Hop

Citra™ is a new special aroma hop variety released by the Hop Breeding Company, (a joint venture between John I. Haas, Inc. and Select Botanicals Group, LLC in the Yakima Valley) having unique and highly favored flavor characteristics. As the name suggests, its flavor descriptors include citrus including lime and grapefruit as well as various tropical fruity characters.

<table>
<thead>
<tr>
<th>Pedigree</th>
<th>50% Hallertau; 25% U.S. Tettnanger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aroma</td>
<td>Strong citrus, fruity</td>
</tr>
<tr>
<td>Alpha Acids*</td>
<td>11.0 - 13.0 %</td>
</tr>
<tr>
<td>Beta Acids</td>
<td>3.5 - 4.5 %</td>
</tr>
<tr>
<td>Cohumulone</td>
<td>22 - 24 % of alpha acids</td>
</tr>
<tr>
<td>Total Oil</td>
<td>2.2 - 2.8 ml/100g</td>
</tr>
<tr>
<td>Myrcene</td>
<td>60 - 65 % of total oil</td>
</tr>
<tr>
<td>Humulene</td>
<td>11 - 13 % of total oil</td>
</tr>
<tr>
<td>Caryophyllene</td>
<td>6 - 8 % of total oil</td>
</tr>
<tr>
<td>Farnesene</td>
<td>&lt; 1 % of total oil</td>
</tr>
<tr>
<td>Storage Stability</td>
<td>Fair</td>
</tr>
</tbody>
</table>
### Storage Stability

*** 6 months at 20 C.

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**CITRA™** is a special aroma hop variety developed by the Hop Breeding Company of Yakima, Washington. Flavors and aromas of beer hopped with **CITRA™** can range among those of tropical fruit, grapefruit, melon, gooseberry, and lychee fruit. **CITRA™** originated from a cross made between the European aroma variety Hallertauer mittelfrueh and a male derived from the variety known as U.S. Tettnang. **CITRA™** is 50% Hallertauer mittelfrueh, and 25% U.S. Tettnang. The variety produces solid yellow-green hop cones that mature in the first week of September.

<table>
<thead>
<tr>
<th>Analytical Data</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Origin</strong></td>
<td></td>
</tr>
<tr>
<td>Yield (per acre)</td>
<td>1400~1600 lbs.</td>
</tr>
<tr>
<td>Alpha Acids* (%)</td>
<td>11 ~ 13</td>
</tr>
<tr>
<td>Beta Acids (%)</td>
<td>3.5 ~ 4.5</td>
</tr>
<tr>
<td>Alpha/Beta Ratio</td>
<td>2.9 ~ 3.1</td>
</tr>
<tr>
<td>Humulone** (%)</td>
<td>76 ~ 78</td>
</tr>
<tr>
<td>Cohumulone (%)</td>
<td>22 ~ 24</td>
</tr>
<tr>
<td>Total Oils (mls/100g)</td>
<td>2.2 ~ 2.8</td>
</tr>
<tr>
<td>Humulene (%)</td>
<td>11 ~ 13</td>
</tr>
<tr>
<td>Caryophyllene (%)</td>
<td>6 ~ 8</td>
</tr>
<tr>
<td>Humulene/Caryophyllene Ratio</td>
<td>1.6 ~ 1.8</td>
</tr>
<tr>
<td>Farnesene (%)</td>
<td>0</td>
</tr>
<tr>
<td>Storage***</td>
<td>25 ~ 35</td>
</tr>
</tbody>
</table>
Some Oxidation Can Be Beneficial

**Sylvan**
- Methyl (E)-geranate
- Pentanoic acid, ethylester
- Acetic acid, heptyl ester
- α-terpineol
- Myrcene
- Terpinen-4-ol
- Caryophyllene oxide

**Citrussy**
- (E)-Geraniol
- Cyclohexane, 1,3,5-trimethyl-7-hydroxy-α-terpineol
- trans-shisool
- sec-Amyl Acetate
- β-citronellol
- Citronellyl acetate
- Nerol
- trans-Z-à-Bisabolene epoxide
- α-calacorene

**Spicy**
- 8-acetoxylinalool
- 8-hydroxylinalool
- 3- nopinone

**Floral**
- Humulene oxide II
- β-eudesmol
- Toluene

**Herbal**
- 2-Propenoic acid, 2-methyl-pentyl ester
- Propionic acid, propyl ester
- Sorelon
- Benzenemethanol
- Benzoic acid, ethyl ester
- Cyclohexanecarboxylic acid, ethenyl ester
- 2-Pentenoic acid, 2-methyl-,(E)-
- 3-Hydroxy-α-damascone
- Dihydrojasnone
- 1-hydroxy-3-methyl-2-butanone
- β-ionone epoxide

**Preference**

**Ester**

Inui, ASBC 2011
Controlling Oxidation

When drying hops, it is beneficial to remove moisture quickly with relatively low heat.

Industry standard has typically been 150 degrees F (65 C) for about 8 to 10 hours. Recent studies have shown that the optimum temperature is variety-dependent and many aroma hops are best dried at a maximum of 135 F (57 C).

Drying temperature and air flow must be sufficient to uniformly dry the hop bed.

Air flow must be high enough for efficient drying, but not so high as to lift the hop bed and create channeling effects.
Controlling Oxidation

Once baled, hops should be immediately placed in cold storage (except when mitigating fire risk)

Storage temperatures can be determined by the expected time hops will be in storage prior to use or processing.

Hop oxidation is considered a 1st order rate of reaction (remember your chemistry?); for every 10 deg C. increase in temperature, the reaction rate will approximately double.

- Example of storage “shelf life” of hops:
  - 20 C  6 months
  - 10 C  12 months
  - 0 C   24 months
  - -10 C 48 months
Pelletizing Hops – Benefits & Drawbacks

Pelleting helps stabilize the hops, particularly if packaged with inert gas such as nitrogen and carbon dioxide.

Increased density of pellets decreases exposure to oxygen.

However, during hammer-milling and pelleting, hop lupulin glands are ruptured which exposes resins and oils directly to the air as well as to entrained oxygen in the pellet.

Milling and pelletizing also develop their own heat and show losses through oxidation.
Pellet Quality & Brewers’ Expectations

Pellet quality and storage stability are huge factors for brewers.

Many brewers require that pellet temperature does not exceed 50 deg C. at anytime during pelleting process.

• Ensure proper pellet die dimensions and configuration.
• Possible cooling of hop powder prior to pelleting or cooling of pellets as they emerge from the die.
  • Haas has hammer-mill in a coldroom (~0 deg C.) prior to hop powder blending and pelleting.

Pellet density & particle size are important in allowing efficient dispersion of hop material in brewkettle, whirlpool and during dry-hopping.
Pellet Quality – Visual & Tactile

Visual: Dull pellet surface is best, with no glossy-hard surface (scorching).

Tactile: Pellets should be crushable with finger pressure, but not so soft that the pellets lose their integrity while handling and in the package.
Pellet Packaging and Storage

Pellet packaging typically in tri-foil material impervious to oxygen ingress (combination of metal and polyester).

Pellets in package flushed with inert gases such as nitrogen and/or carbon dioxide.

Pellet “best-by” designations when packaged properly:

• 3 years at 0-5 deg. C.
• 5 years at < -10 deg C.
Hops & Pellet Analysis

UV Spectrophotometric analysis most common for bitter acids, but HPLC most accurate; GC for volatile aromas.

Three parameters of primary interest to brewer:

- % alpha acids – UV Spectro
- Essential oil content – distillation (ml/100 grams hops)
- Hop Storage Index (HSI) – UV Spectro
Hop Storage Index - HSI

HSI is determined by spectrophotometric method (ASBC Hops 6a, 12); gives indication of loss of alpha acids.

- 0.250  Typical of fresh hops
- 0.300  10% oxidized
- 0.400  25% oxidized
- 0.500  33% oxidized
- 0.700  50% oxidized

Although HSI measures the degree of degradation of alpha acids, one can also assume that the aroma components of the hops experience a similar exposure to oxidation.

HSI is important to brewers as a quality indicator of hop harvesting, processing, handling, packaging and storage.
Final Thoughts
Thanks for your attention!

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