Hop (Humulus lupulus L.) female flowers develop into cones and produce small yellow substances called lupulin glands. Acid and essential oil compounds contained in lupulin glands impart bitterness and aroma to beer. Because the chemical composition changes as cones mature, it is critical to harvest hops at the optimum maturity stage. This article explains how to determine the optimum time to harvest hops. It is part of a series that examines the challenges and opportunities of hop production in Florida based on research at the UF/IFAS Gulf Coast Research and Education Center (UF/IFAS GCREC). A corresponding tutorial video is available at https://youtu.be/U6i8rh65jyU. Additional videos on hop production and management are also available at the UF IFAS Horticultural Crop Physiology Lab YouTube channel (https://www.youtube.com/channel/UCMyYaifZsi6d4ZI-eaxCTQ). The intended audience for this article includes growers, certified crop advisors, crop consultants, and UF/IFAS Extension faculty.

Hops Produce Two Crops per Year in Florida

Florida's subtropical climate, along with flowering control using supplemental lighting, enables double-season production of hops (Agehara 2000; Agehara et al. 2021). Spring harvest occurs in June, and fall harvest occurs from October to November, depending on cultivars and timing of flower induction. The video describing spring and fall growth cycles of hops in Florida is available at https://youtu.be/_rAnXr3cQrs. Three methods to determine the optimum time to harvest hops are described below.

**Method 1: Sensory Assessment**

The ripeness of cones can be measured based on sensory attributes, including appearance, touch, and smell. Sensory assessment is a conventional method that can be performed readily without any special tools.

**By Color**

- Ripe cones have light-green to yellowish bracts with some browning on tips (Figure 1). Immature cones look greener than ripe cones.

![Figure 1. Ripe cones of ‘Cascade’ hops grown at the UF/IFAS GCREC. Credits: Shinsuke Agehara, UF/IFAS](https://example.com/image.jpg)
• As cones mature, lupulin glands turn golden yellow from pale yellow (Figure 2).

By Touch
• Ripe cones feel dry and papery, whereas immature cones feel damp and soft.
• Ripe cones should bounce back when you squeeze them. Immature cones will stay compressed.
• Lupulin glands in ripe cones should be sticky to the touch.
• Ripe cones should make a papery sound when you roll them between your fingers.

By Smell
• Roll some cones back and forth between your hands and give them a good sniff. Ripe cones should have an intense aroma that is specific to a given cultivar (Table 1).
• Immature cones smell grassy, whereas overripe cones have onion- or garlic-like off-flavors.

Method 2: Preharvest Quality Analysis
The most accurate and reliable method to determine the optimum harvest time is having cones analyzed in a laboratory. Most laboratories offer both preharvest and complete analysis options. In general, preharvest analysis includes α acid, β acid, cone moisture, and hop storage index, whereas complete analysis also provides the concentration and composition of essential oils. Individual tests on acids or essential oils may also be available. Contact your laboratory for services offered, quantities of cones needed for testing, and recommended shipping methods.

Sampling
It is critical to collect a sample that is representative of what will be harvested. Not all cones reach full maturity at the same time in the field. Immature cones should be included in the sample in proportion to their presence, unless you plan to harvest only ripe cones by hand picking. The sample should consist of cones collected from different heights on the trellis, as well as from sun-exposed and shaded sides of bines. It is also advised to collect cones from multiple plants in different locations within the same hopyard, which can then be combined to make up a composite sample.

Shipping
In general, preharvest acid analysis requires at least 30 g of cones, whether they are fresh or dried, whereas essential oil analysis requires at least 100 g of cones. To minimize quality loss during shipping, we recommend vacuum-sealing cones and using overnight shipping. Avoid shipping samples at the end of the week. Loosely packed cones can lose lupulin glands by being shaken during shipping. Fresh cones should be shipped overnight with dry ice the same day they are collected.

It is important to note that drying procedures affect cone quality and thus analytical results. If your objective is only to determine the optimum harvest time, we recommend sending fresh cones to avoid data variability induced by the deviation in drying temperature and time. If you have a forced-air oven capable of consistent drying and are planning to sell whole dried cones, however, you may consider sending dried cones because they are more representative of your final product than fresh cones.

Data Interpretation
Check if test results are in the normal range for the cultivar tested. At the optimum harvest time, cone moisture ranges from 75% and 80% (Mabie 2021), and the hop storage index should be below 0.30 (Nickerson and Likens 1979). Acid and essential oil levels vary among hop cultivars. According to the Hop Growers of America (2017), ‘Cascade’ hops typically contain 4.5% to 7% α acids, 4.8% to 7% β acids, and 0.7 to 1.4 ml of essential oils in 100 grams (Table 1). The concentration of cohumulone in total α acids ranges from 33% to 40% (Table 1).

Labs Offering Analytical Services for Hops
There are both commercial and university laboratories that provide analytical services for hops. Contact individual laboratories for services offered, testing fees, quantities of cones needed for testing, and shipping methods. Our
samples have been analyzed by the laboratories listed below. Please note that mention of commercial services in this article is for identification only and does not imply endorsement by the UF/IFAS Extension nor discrimination against similar services not mentioned.

• **AAR Lab**
  2517 Advance Rd. Ste A, Madison, WI 53718
  608-622-7522
  [https://www.aarlab.com/](https://www.aarlab.com/)
  info@aarlab.com

• **Alliance Analytical Laboratories**
  179 W Randall St, Coopersville, MI 49404
  616-837-7670
  jeremy@aatestlabs.com

• **Cornell Craft Beverage Analytical Lab**
  Cornell AgriTech-110 Food Research Laboratory
  665 W. North Street, Geneva, NY 14456
  [https://cals.cornell.edu/cornell-agritech/our-expertise/craft-beverage-production/craft-beverage-analytical-lab](https://cals.cornell.edu/cornell-agritech/our-expertise/craft-beverage-production/craft-beverage-analytical-lab)

### Method 3: Cone Moisture

The moisture content in cones declines as they mature. At the optimum harvest time, cones typically have a moisture content between 75% and 80% and a dry matter content between 20% to 25% (Mabie 2021). A good general target is 77% moisture or 23% dry matter.

#### Sampling

Use the sampling procedure described above under “Method 2: Preharvest Quality Analysis.”

#### Drying

1. Weigh the empty paper bag to hold your sample and record the weight (bag wt).
   - Kraft paper bags (2 lb size) are ideal.
   - Use a scale with a readability of at least 0.01 oz or 0.1 g.

2. Place about 2 oz or 50 g of fresh cones in the paper bag and record the weight (total fresh wt: paper bag + sample).
   - Leave cones loose in the bag.
   - Do not close the bag.

3. Dry the sample in an oven at 175°F (80°C) to a constant weight and record the weight (total dry wt: paper bag + sample).
   - Leave the bag open during drying.
   - When drying multiple samples at the same time, keep at least 2" (5 cm) of space between bags to allow air to circulate.
   - Reheat and reweigh the sample until a constant weight is obtained.

#### Moisture Calculation

Calculate the moisture content of your sample using the equation below.

\[
\text{Cone moisture (\%)} = \left(1 - \frac{\text{Total dry wt} - \text{Bag wt}}{\text{Total fresh wt} - \text{Bag wt}}\right) \times 100
\]

#### Literature Cited


Table 1. Typical quality characteristics of selected hop cultivars.\(^1\)

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Alpha acid (%</th>
<th>Beta acid (%</th>
<th>Cohumulone (% alpha acid</th>
<th>Essential oil (ml/100 g</th>
<th>Aroma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cascade</td>
<td>4.5–7.0</td>
<td>4.8–7.0</td>
<td>33–40</td>
<td>0.7–1.4</td>
<td>Citrus; Grapefruit; Floral; Spicy</td>
</tr>
<tr>
<td>Comet</td>
<td>9.0–11.0</td>
<td>4.0–6.0</td>
<td>38–42</td>
<td>1.0–1.5</td>
<td>Grapefruit; Citrus</td>
</tr>
<tr>
<td>Nugget</td>
<td>11.5–14.0</td>
<td>4.2–5.8</td>
<td>22–26</td>
<td>1.8–2.2</td>
<td>Lime; Ginger; Pineapple; Geranium; Lychee</td>
</tr>
<tr>
<td>Zeus</td>
<td>12.0–16.5</td>
<td>4.0–6.0</td>
<td>27–35</td>
<td>1.0–2.0</td>
<td>Sweet citrus; Herbal</td>
</tr>
</tbody>
</table>

\(^1\) Source: Hop Growers of America (2017).
\(^2\) Cultivars that are adapted to subtropical climate conditions are included in this table.