UCDAVIS BREWING PROGRAM

UCDAVIS FOOD SCIENCE AND TECHNOLOGY

Analytical Report-EvodiaBio

Investigating beer loss as a function of dry-hop rate

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Description

In conjunction with brewing trials, sensory analysis, and aroma profiling of Evodia's Yops® product, the relative loss of beer due to traditional dry-hopping methods using pelletized hops was investigated. At benchtop scale, conical vessels were modified to match a common geometric ratio of conical fermenters found in the craft brewing industry. In quintuplicate replicates (n=5), known amounts of beer were separately combined with three popular hop varieties at five different dry-hopping rates. These factors were chosen to elucidate potential variation in absorption capacities and settling characteristics of the pelletized hop material. Beer samples were incubated with hop pellets for 72 hours at 20°C then cold-crashed and incubated at 0°C for 48 hours to simulate common craft brewery practices. The supernatant beer was manually separated from the settled solids and measured for liquid volume and mass. The relative losses due to dry-hopping were calculated from the differences in the initial amount of beer added to the vessel compared to the amount of recoverable beer after cold-settling. Considering Yops® is a liquid, beer-miscible product designed to replicate aroma profiles of hops, this study aims to elucidate the potential increase in batch yield for craft brewers when supplementing Yops® for solid hop pellets, without the need for additional clarification steps such as pad or plate-and-frame filtration or centrifugation.

Procedure

50-mL conical Eppendorf tubes were modified to match the Height : Diameter ratio of conical fermentors commonly found in commercial craft breweries (2.4 : 1). T-90 Mosaic, Amarillo, and Citra hop pellets (BSG™ Select Hops, Washington, USA, Harvest Year: 2024) were chosen for the study as they are popularly used in dry-hopping of select craft beer styles[1] and display different hydration properties, likely due to their varying oil and α -acid contents (Table 1). Five different dry-hop rates – 2 g/L, 5 g/L, 7 g/L, 10 g/L, and 12 g/L – were chosen to investigate a range of dosages found across craft beer styles. Each variety and dry-hop rate was tested in quintuplicate (n=5).

Hop pellets were manually weighed into each conical tube and combined with 25.00mL of degassed Light American Lager (ABV = 4.2%) via automatic repeater pipet.

Variety	Average Oil Content (mL/100g)	α-acid (w/w)
Mosaic	1.2	10.6%
Amarillo	1.7	7.1%
Citra	1.7	14.5%

Table 1: Hop Pellet Properties (given by supplier)

The initial beer volume, beer mass, hop mass and Eppendorf tube weight were all recorded. Samples were then placed into a temperature-controlled incubator set at 20°C for 72 hours then transferred to a refrigerated incubator for 48 hours to simulate common commercial brewing practices of dry-hopping and cold-settling.[2]

To determine the recoverable amount of beer from each sample, the inlet tubing (35mm diameter) of a Masterflex™ 77200-62 Peristaltic Pump was inserted into the supernatant beer, while the outlet was placed into a 25mL volumetric graduated cylinder (Accuracy = 0.1mL). As the pump was initiated, the inlet line was gradually lowered into the sample tube as the liquid supernatant level dropped. When solid hop material began entering the transfer line, the pump was shut off, and the remaining liquid in the line was transferred to the graduated cylinder. The recoverable beer volume as well as the mass of the wet hop material and Eppendorf tube were recorded for all 75 samples. Overall "beer loss" was calculated by comparison to each sample's initial volumes and masses.

Results

Figure 1 displays the full dataset calculated from the percentage volumetric loss of beer as a function of dry-hop rate, disregarding hop variety. The clustering of each grouping as well

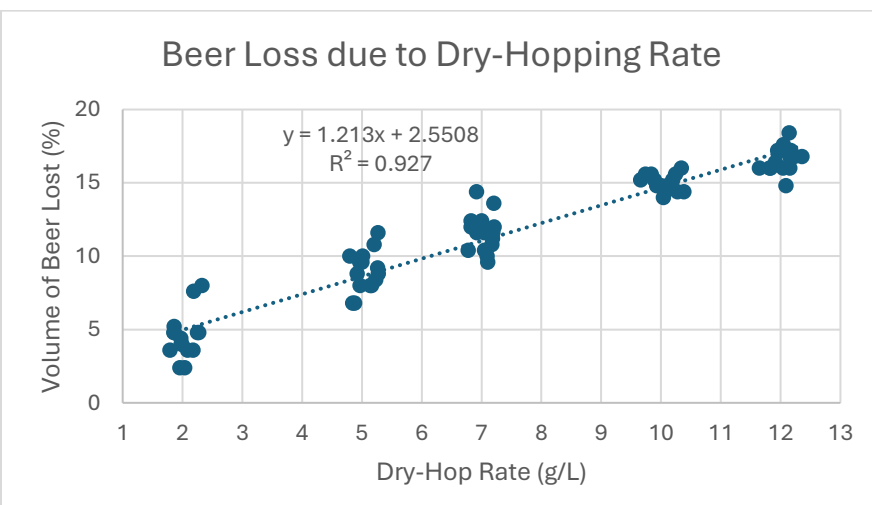


Figure 1: The average percent volume of unrecoverable beer based on dry-hop rate.

a linear R^2 value of 0.93 provides confidence that the experimental design was sound and that the variety of hop had minimal differences in absorption capacity and settling characteristics under the given conditions. This was further supported by comparing the variety-specific datasets (Figure 4). Figure 2 displays the average percentage of beer lost considering each approximate dry-hop rate, and a positive, relatively linear correlation is seen.

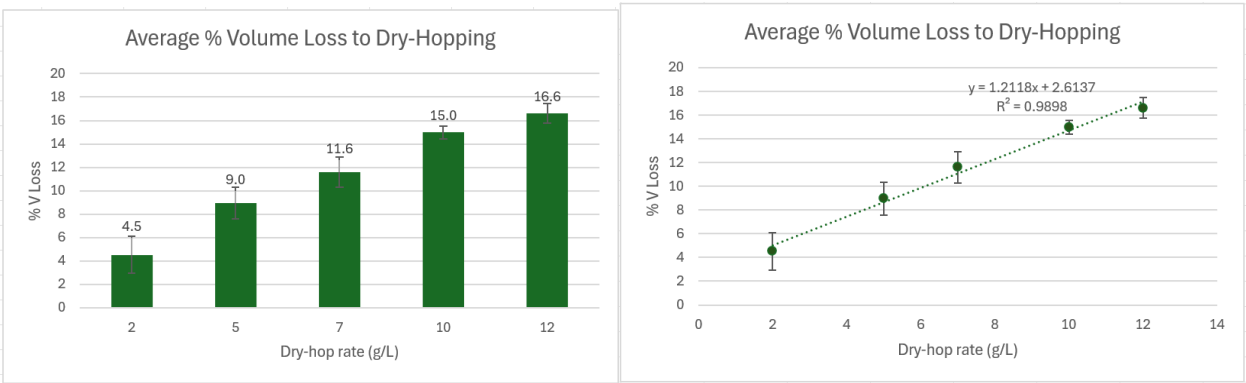


Figure 2: (Left) The average percentage of unrecoverable beer for each approximate dry-hop rate investigated (disregarding hop variety). Error bars represent standard deviation. All groups were determined to be significantly different from one another by means of Single-factor ANOVA/Tukey Post Hoc test. (Right) Linear trendline equation and R^2-value.

Interestingly, when considering the ratio of beer volume loss (in Liters) per mass of hop material added (disregarding hop variety), the lowest dry-hop rate investigated, 2g/L, had the highest relative value (Figure 2). All other groups with regard to dry-hop rate were statistically similar.

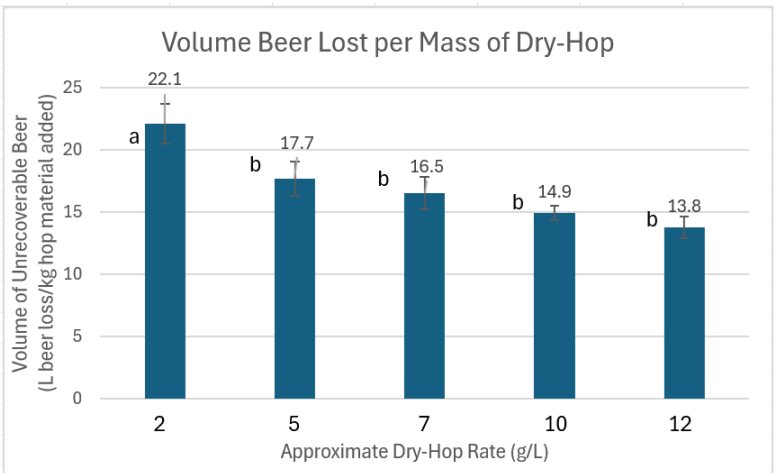


Figure 3: Average volume (L) of beer lost per kg of hop material. Error bars represent standard deviation. Significant differences determined by Single-

factor ANOVA/Tukey Post Hoc test indicated by alphabetic lettering.

Figure 4 shows the variety-specific results for percentage of beer volume losses. All datasets of differing dry-hop rates were shown to be statistically different from one another (not indicated on Figure). All datasets of the same dry-hop rate were shown to be statistically similar except for the 7g/L trials (indicated in Figure by alphabetic lettering). These differences, however, were minimal. Figure 4 also displays the linear trendlines fit to the average values of each hop variety. All R^2-values were above 0.97.

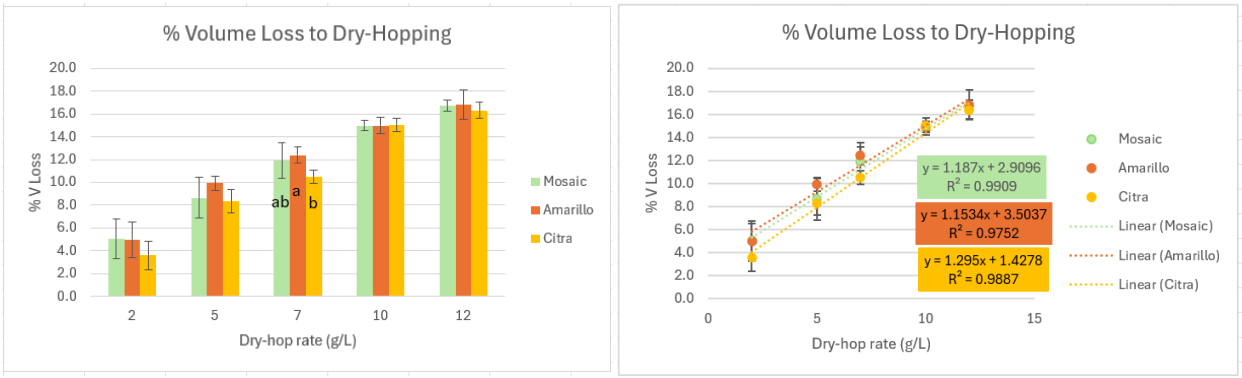


Figure 4: (Left) The average percentage of unrecoverable beer (% V lost) for each hop variety and approximate dry-hop rate investigated . Error bars represent standard deviation. Statistical differences were determined by means of Single-factor ANOVA/Tukey Post Hoc test. (Right) Linear trendline equations and R^2-values.

Discussion

The surprising result of the 2g/L trial having a significantly higher value for Beer Loss (L) per Dry-Hop Mass (kg) – shown in Figure 3 – could simply be a mathematical result of utilizing such small quantities of hop material for these benchtop trials or a possible indication of less efficient recovery due to the smaller surface area of the settled hop material residing lower in the vessel's cone. Alternatively, the 2g/L samples may have had less efficient compaction/settling of the solid material, leading to a more difficult/less consistent removal of the supernatant layer without disturbing the solid bed. This is further supported by the fact that all other dry-hop rates showed statistically similar averages for the ratio of beer lost (L) per hop material added (kg). When averaging the values of the 5g/L, 7g/L, 10g/L, and12g/L datasets, the average value equates to **15.7±2.2** L Beer lost/kg hop pellets. In comparison, the total average with all datasets included is **17.0±4.38** L Beer lost/kg hop pellets. The difference in the overall average is minimal if considering commercial scale operations, but the variance in the latter dataset is rather high. When considering the percentage of potentially recoverable beer, however, clear trends emerge within the data.

As a larger dry-hop rate is utilized, the percentage of unrecoverable beer increases. Within the chosen range for this study, the trend is relatively linear, though shows potential signs of fitting a logarithmic curve. Further data is needed to validate this claim.

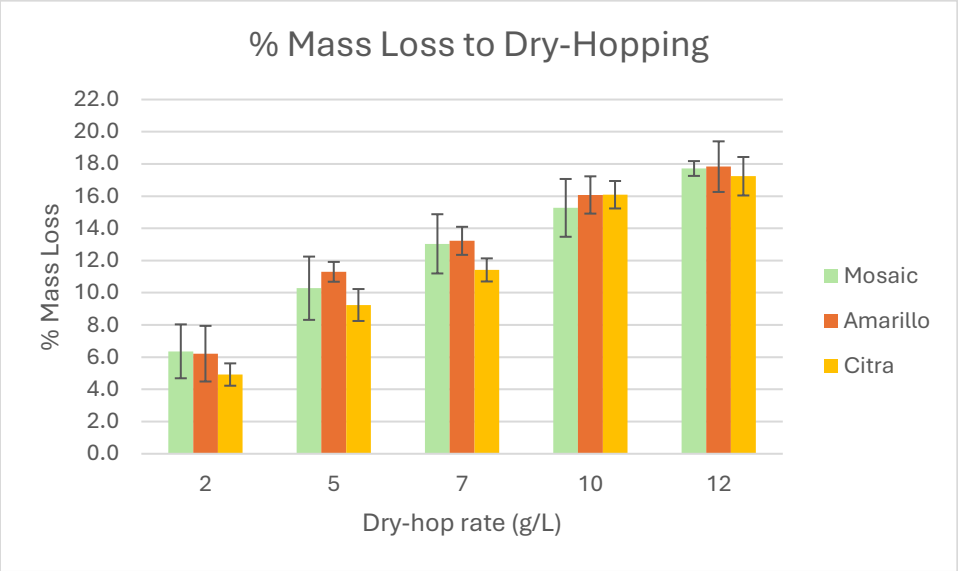
Conclusion

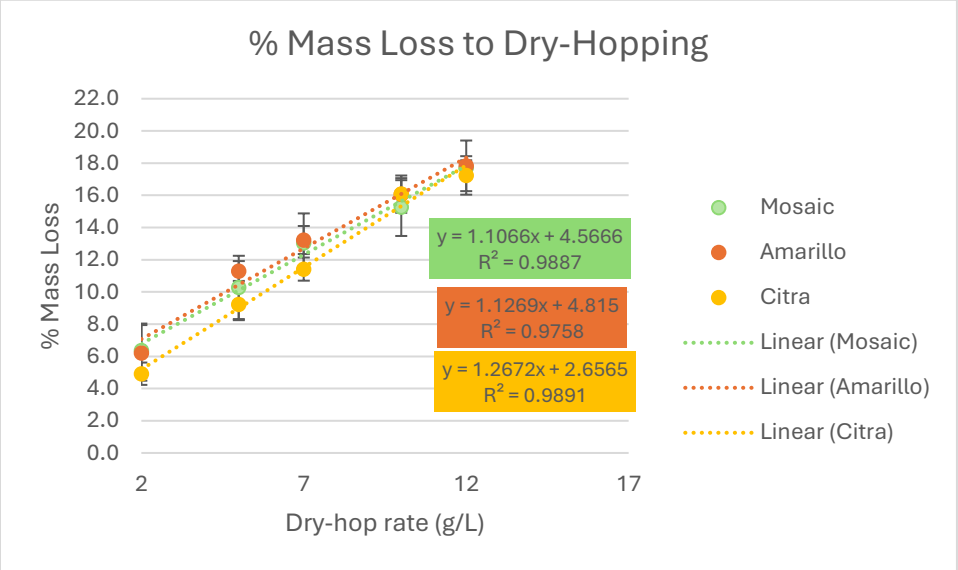
When considering the variability in commercial craft brewery practices, operators, vessel geometry, and brewing recipes, the values and trends shown by the benchtop study seem reasonable with regard to beer loss due to dry-hopping with T-90 pellets. Though a much larger dataset is likely needed to construct an accurate, predictive model for industry-application, the relatively linear responses between the treatments and average values generated seem in agreement with industry expectations.[3] Given the potential volumetric losses of product due to dry-hopping, the development and commercialization of fully-miscible aroma products for supplementing solid hop character in beer products has the potential to save craft brewers a sizeable amount of capital as long as the quality of the final product is not jeopardized. If able to fully replace traditional dry-hopping methods, EvodiaBio's Yops® product has the potential to reduce a brewery's storage space requirements, reduce or eliminate physical filtration/separation operations, and increase batch yields by up to 17% based on the results of these benchtop trials.

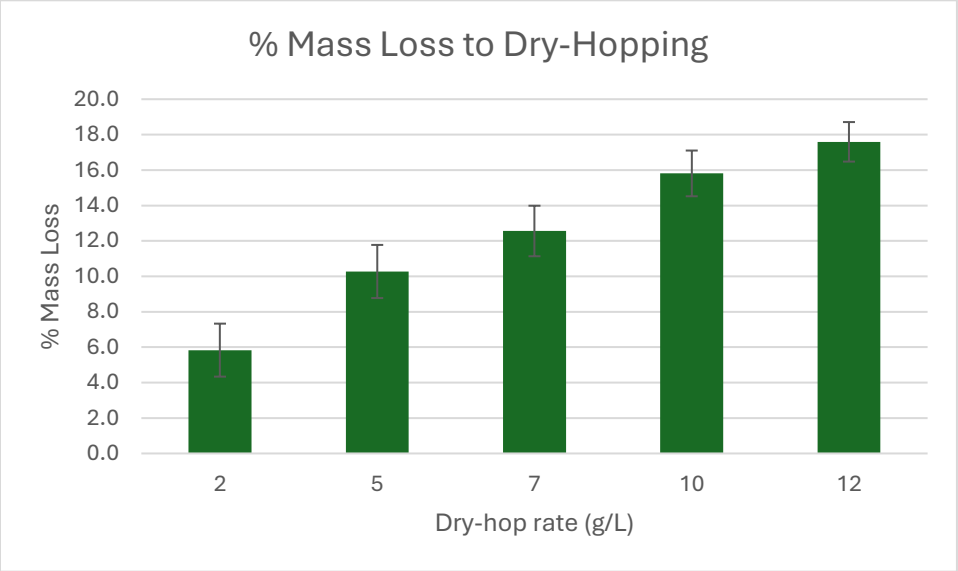
References

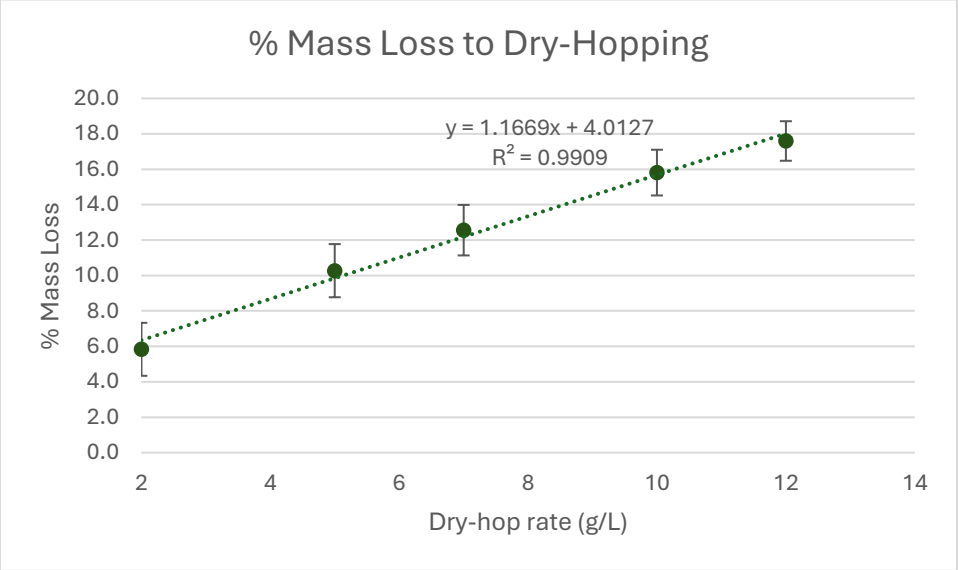
1) Cibaka, M. L. K., Ferreira, C. S., Decourrière, L., Lorenzo-Alonso, C. J., Bodart, E., & Collin, S. (2017). Dry Hopping with the Dual-Purpose Varieties Amarillo, Citra, Hallertau Blanc, Mosaic, and Sorachi Ace: Minor Contribution of Hop Terpenol Glucosides to Beer Flavors. *Journal of the American Society of Brewing Chemists*, *75*(2), 122–129. https://doi.org/10.1094/ASBCJ-2017-2257-01
2) Oladokun, O., James, S., Cowley, T., Smart, K., Hort, J., & Cook, D. (2017). Dry-hopping: the effects of temperature and hop variety on the bittering profiles and properties of resultant beers. BrewingScience, 70(6), 187-196. http://dx.doi.org/10.23763/BrSc17-18oladokun.
3) De Oliveira Gomes, F., Guimaraes, B.P., Ceola, D., Ghesti, G.F., Sociedade Brasileira de Ciência e Tecnologia de Alimentos*Food Sci. Technol (Campinas)* 42 • 2022

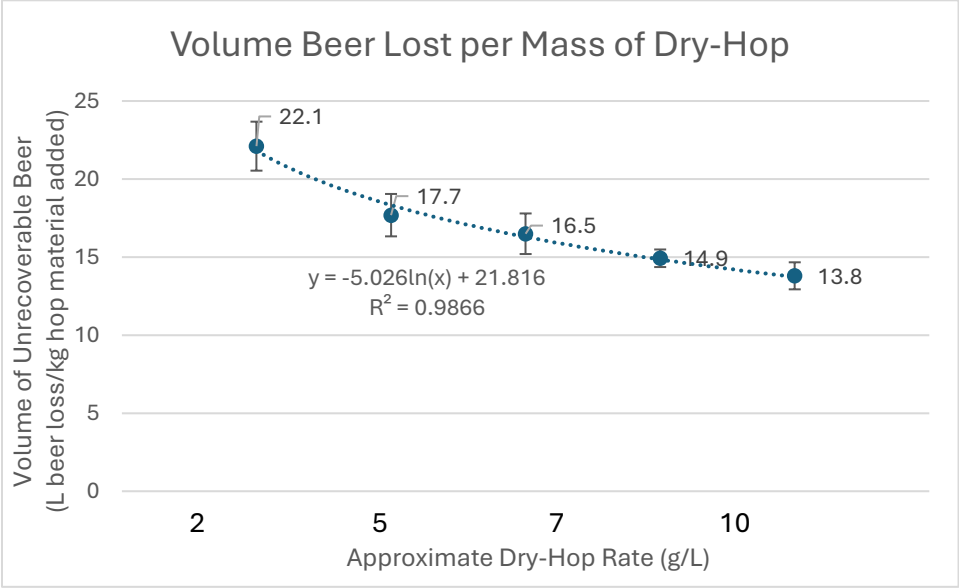
Supplemental Figures

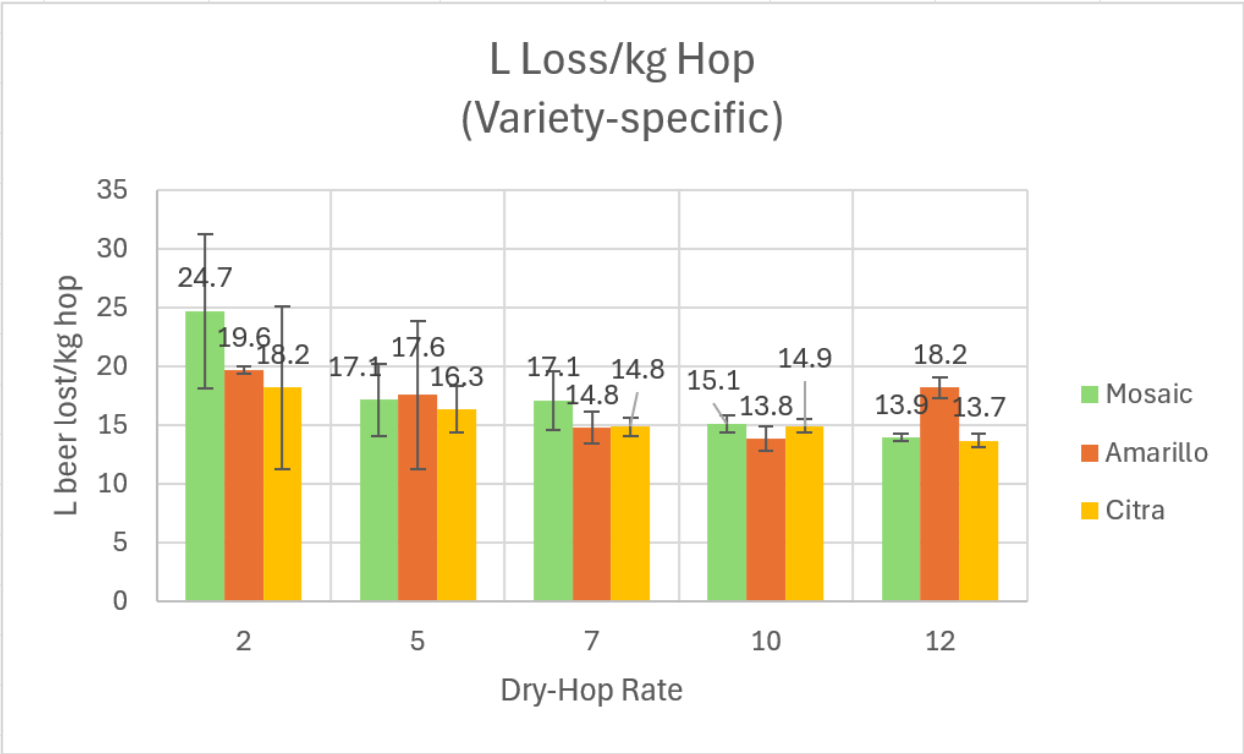





% Mass Loss to Dry-Hopping
% Mass Loss
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
2
5
7
10
12
Dry-hop rate (g/L)


% Mass Loss to Dry-Hopping
y = 1.1669x + 4.0127
R² = 0.9909
% Mass Loss
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
2
4
6
8
10
12
14
Dry-hop rate (g/L)


Volume Beer Lost per Mass of Dry-Hop
Volume of Unrecoverable Beer
(L beer loss/kg hop material added)
25
20
15
10
5
0
22.1
17.7
16.5
14.9
13.8
y = -5.026ln(x) + 21.816
R² = 0.9866
2
5
7
10
Approximate Dry-Hop Rate (g/L)


L Loss/kg Hop
(Variety-specific)
L beer lost/kg hop
35
30
25
20
15
10
5
0
24.7
19.6
18.2
17.1
17.6
16.3
17.1
14.8
14.8
15.1
13.8
14.9
13.9
18.2
13.7
2
5
7
10
12
Dry-Hop Rate
Mosaic
Amarillo
Citra