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#ElevateBeer

Dry Hopping of Beer

Examining Practical Variables in a Regional Craft Brewery

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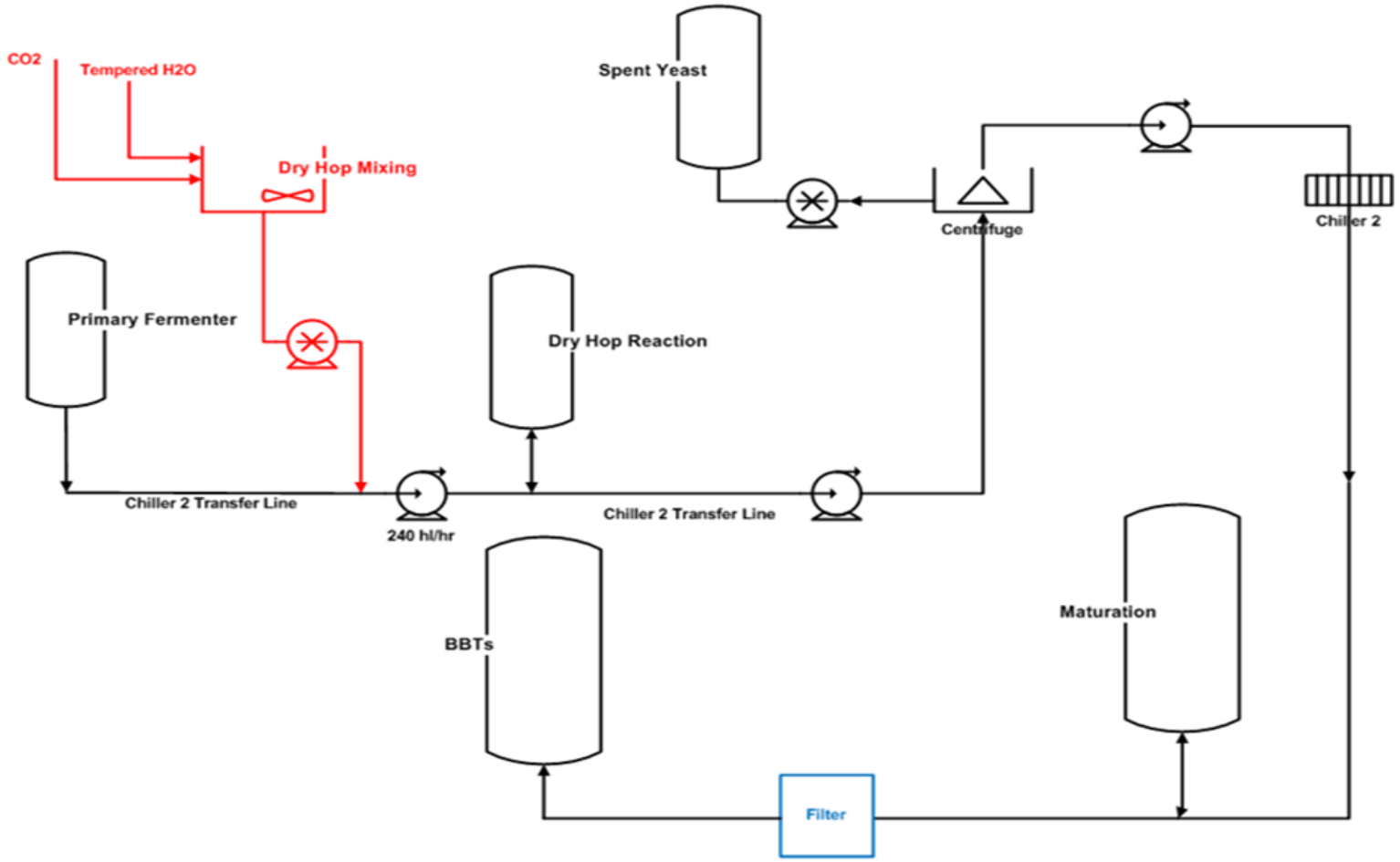
Introduction & Outline

- Objective
- Current Practice
- Key Variables & Experimental Design
- Laboratory Practice
- Results & Data Analyses
- Conclusions & Opportunities

Objective

Investigate opportunities within the current process to optimize dry hop aroma potential without fundamentally changing beer flavor profile.

Current Practice



Key Variables

- Beer temperature - 6°C & 12°C
  - What is the influence of temperature on key aroma compounds?
- Hop dosing rate - 125 g/hL, 250 g/hL & 500 g/hL
  - Does more = better?
  - What is the influence when other variables are considered?
- Beer alcohol content – 7.5% ABV & 9.5% ABV
  - How does alcohol concentration influence the occurrence of hop aroma compounds from dry hopping?
- Hop pellet type - T90 & Enhanced T90 (E90)
  - Do we realize better transfer of key terpenes into beer with one pellet type?
  - Is there an improvement in processing capabilities with E90 vs. T90?

Experimental Design

Outline of Laboratory Trials

- Four-way, full factorial test design.
- Investigated four key parameters of the dry hop process: Beer temperature, beer ABV%, hop pellet type, hop dosing rate.
- 72 replicates in total.

Factor	A	B	C	D		Response Template		
	Temperature	ABV	Pellet Type	Dosing Rate		Y1	Y2	Y3
	6	7.5	T90	125				
	6	7.5	T90	250				
	6	7.5	T90	500				
	6	7.5	E90	125				
	6	7.5	E90	250				
	6	7.5	E90	500				
	6	9.5	T90	125				
	6	9.5	T90	250				
	6	9.5	T90	500				
	6	9.5	E90	125				
	6	9.5	E90	250				
	6	9.5	E90	500				
	12	7.5	T90	125				
	12	7.5	T90	250				
	12	7.5	T90	500				
	12	7.5	E90	125				
	12	7.5	E90	250				
	12	7.5	E90	500				
	12	9.5	T90	125				
	12	9.5	T90	250				
	12	9.5	T90	500				
	12	9.5	E90	125				
	12	9.5	E90	250				
	12	9.5	E90	500				

Materials & Laboratory

- Hop pellet types were produced from identical blends of Cascade hops grown in Washington state.
- Un-dry hopped IPA, sampled after centrifugal yeast removal per normal dry hopping operations and placed in frozen storage.
- Beer ABV% adjusted during trial sample preparation.
- Dry hop reactions took place in 500 mL glass bottles in a temperature controlled water bath on a submersible stir plate.
- Reaction times were 24 hours.
- Beer samples centrifuged and pipetted into 5mL vials, then frozen prior to GC-MS analysis.
- GC-MS Analysis: SIM; Extraction = 10 min. at 60°C w/ SPME 50/30um DVB/CAR/PDMS 2 cm; Column: DB5-MS UI 60 mx 32 um x 1 um.

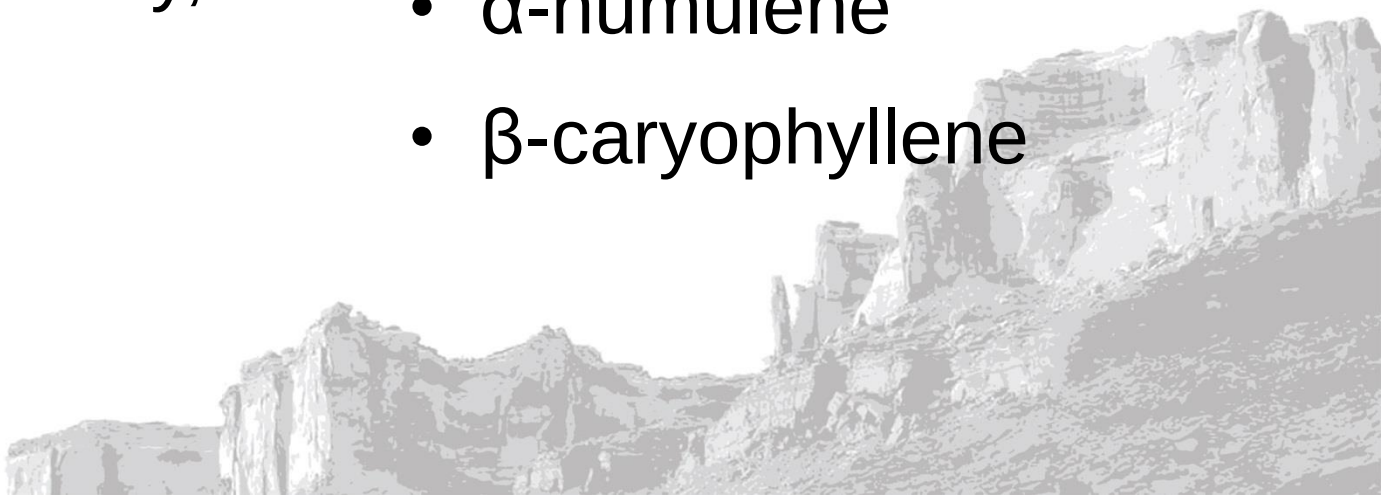
Key Aroma Compounds

IPA Aroma Descriptors:

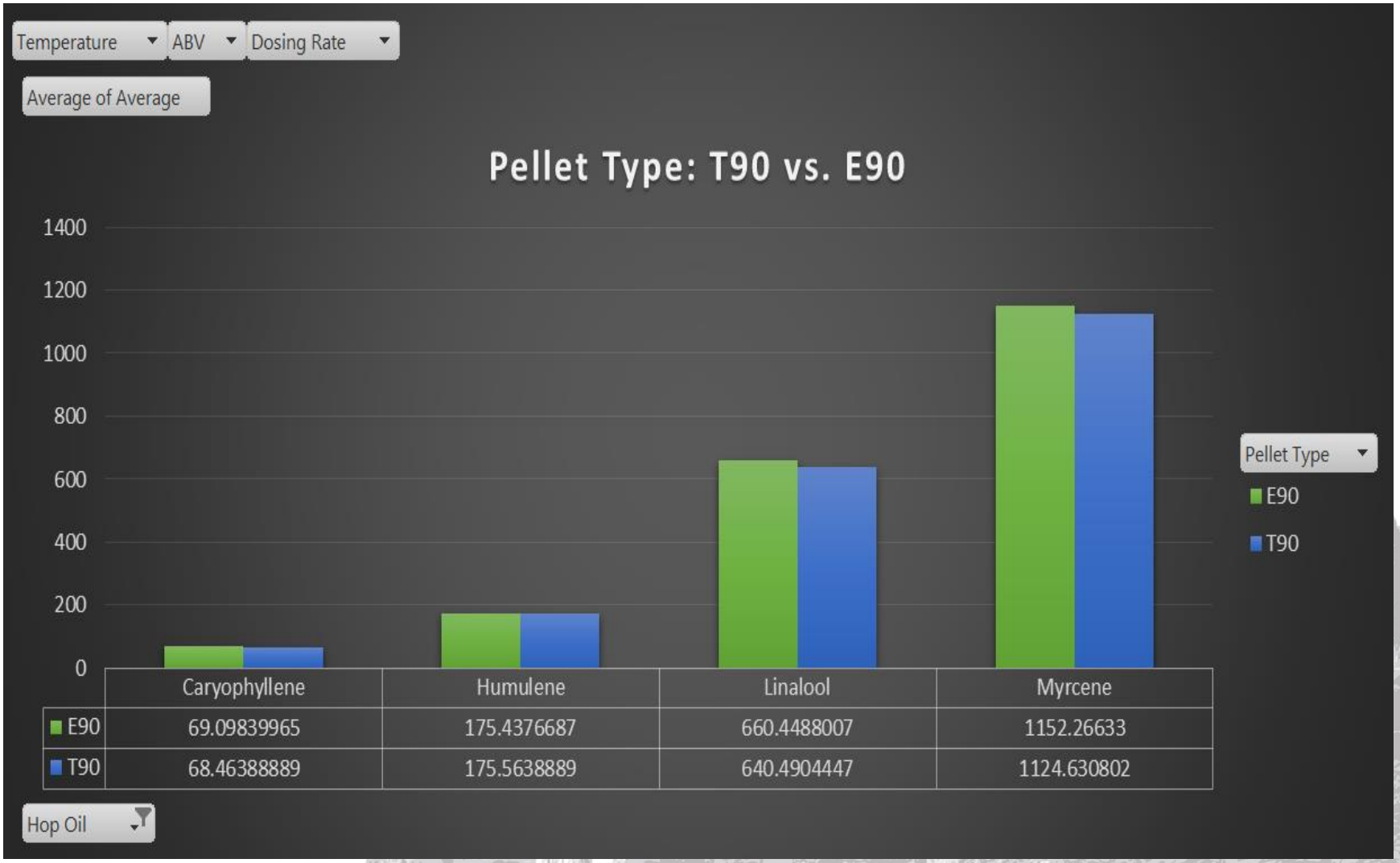
- High amounts of myrcene, citrus (grapefruit), some green tea, grassy, linalool.

Key Compounds Analyzed in Beer:

- Myrcene
- Linalool
- α-humulene
- β-caryophyllene

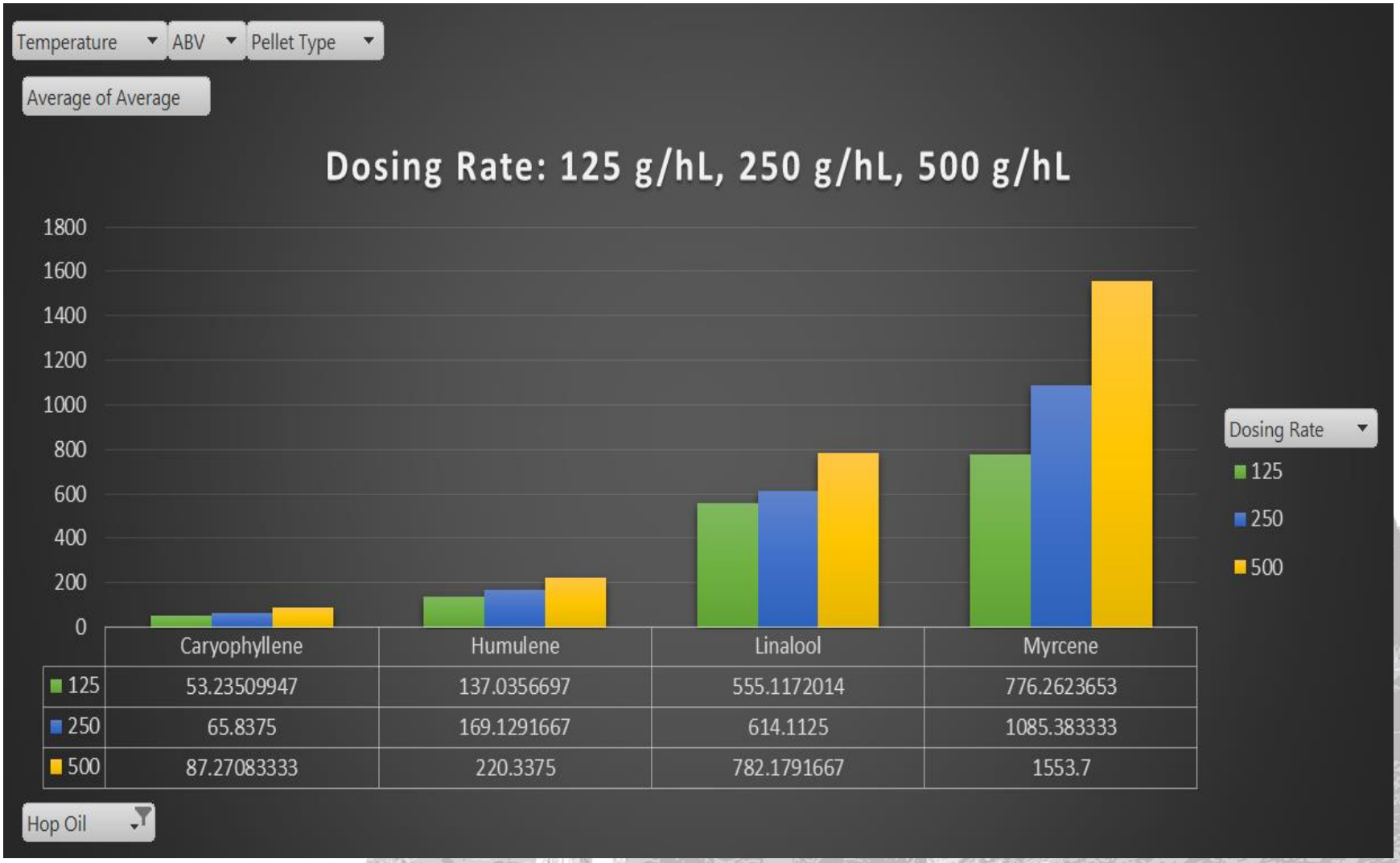


Results: Influence of Pellet Type



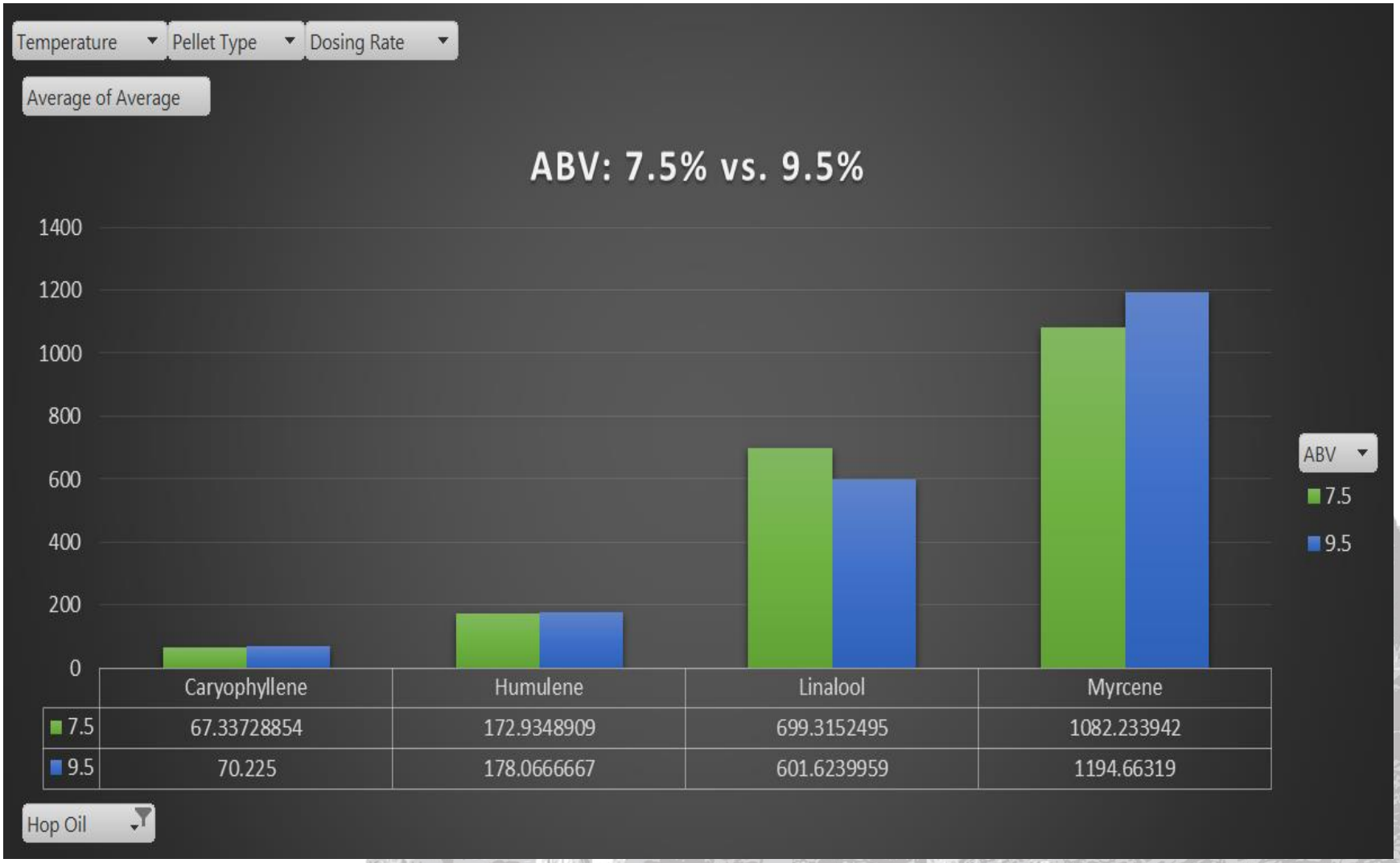
	Caryophyllene	Humulene	Linalool	Myrcene
E90	69.09839965	175.4376687	660.4488007	1152.26633
T90	68.46388889	175.5638889	640.4904447	1124.630802

Results: Influence of Dosing Rate



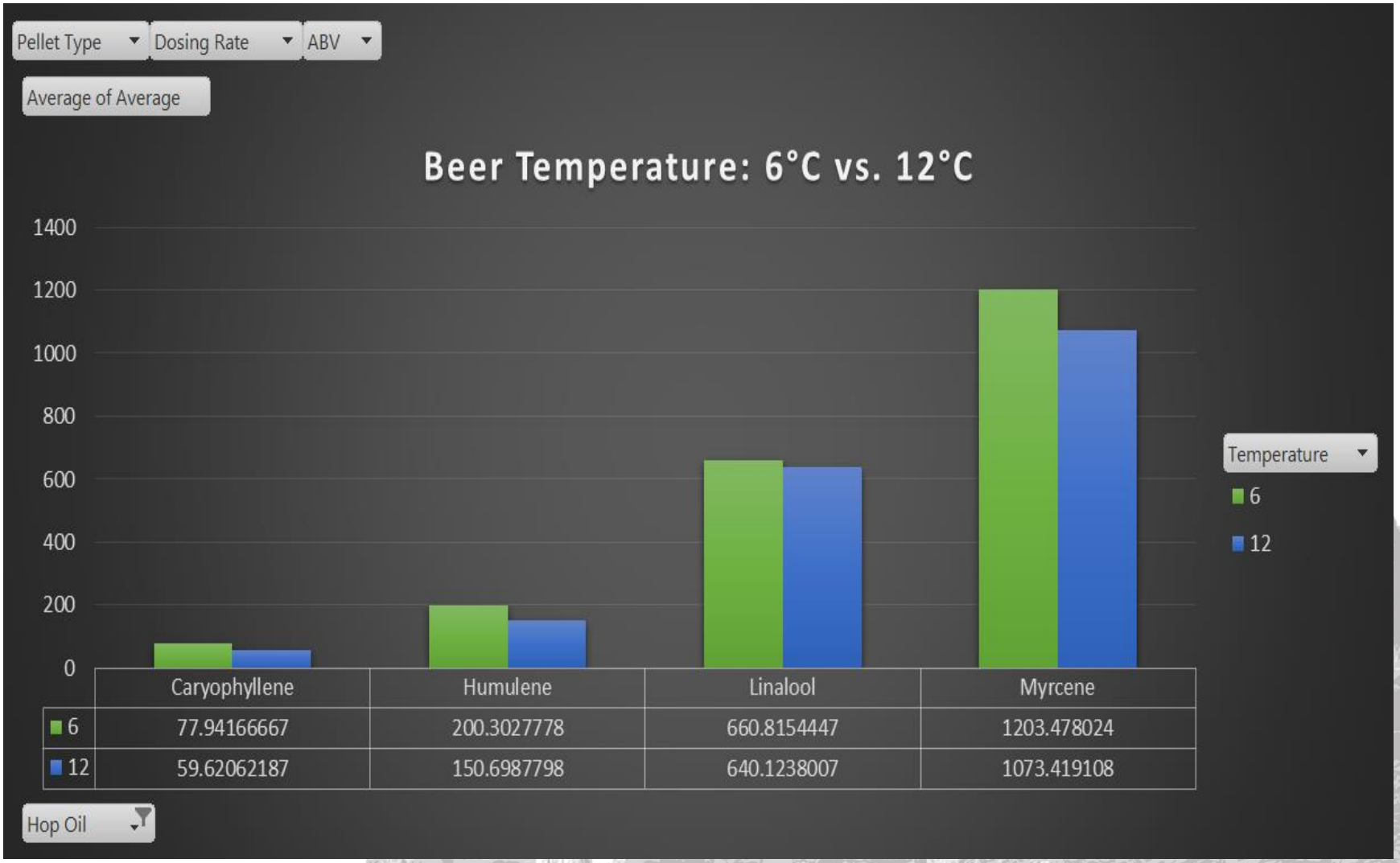
	Caryophyllene	Humulene	Linalool	Myrcene
125	53.23509947	137.0356697	555.1172014	776.2623653
250	65.8375	169.1291667	614.1125	1085.383333
500	87.27083333	220.3375	782.1791667	1553.7

Results: Influence of ABV



	Caryophyllene	Humulene	Linalool	Myrcene
7.5	67.33728854	172.9348909	699.3152495	1082.233942
9.5	70.225	178.0666667	601.6239959	1194.66319

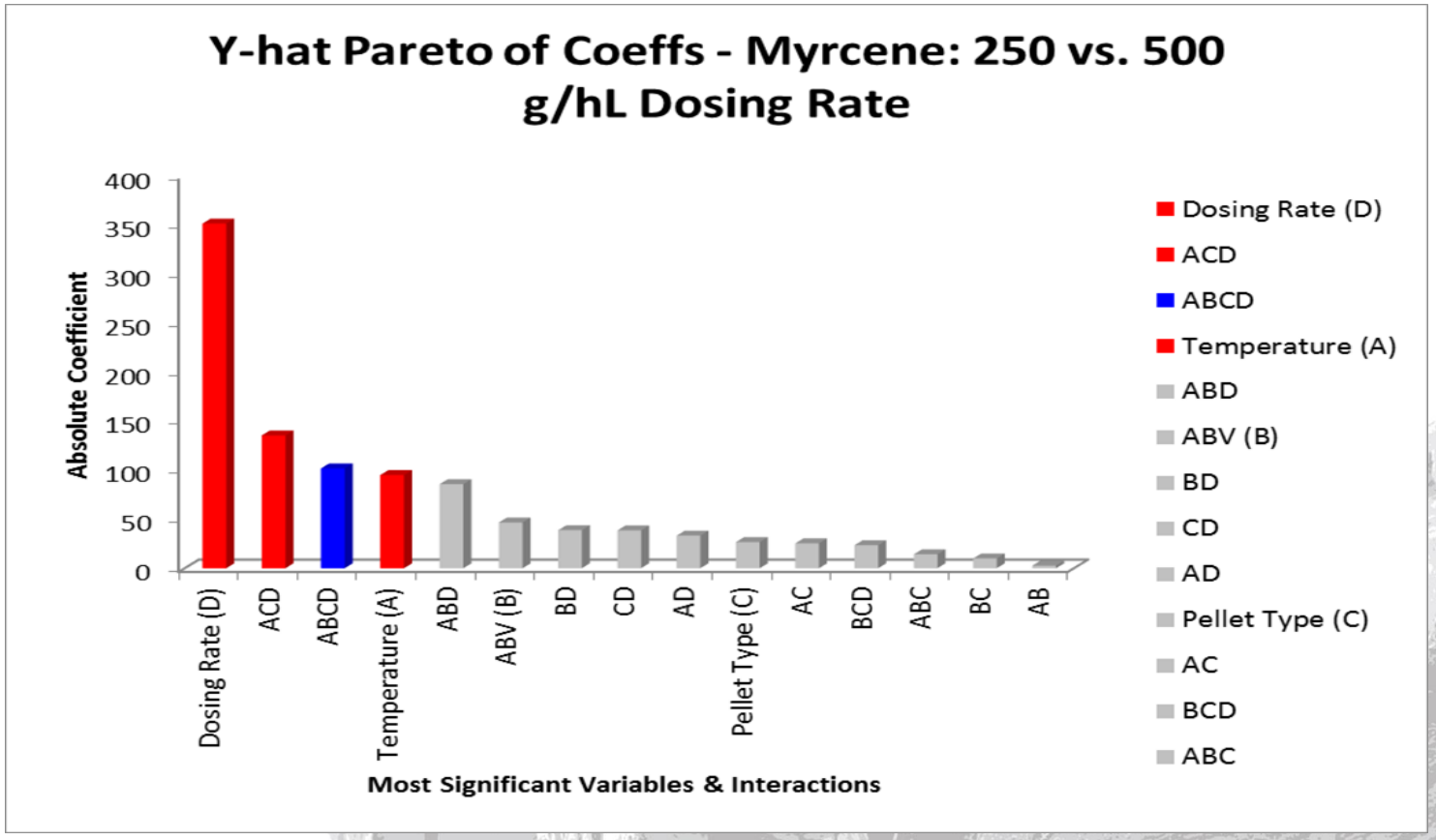
Results: Influence of Temperature



	Caryophyllene	Humulene	Linalool	Myrcene
6	77.94166667	200.3027778	660.8154447	1203.478024
12	59.62062187	150.6987798	640.1238007	1073.419108

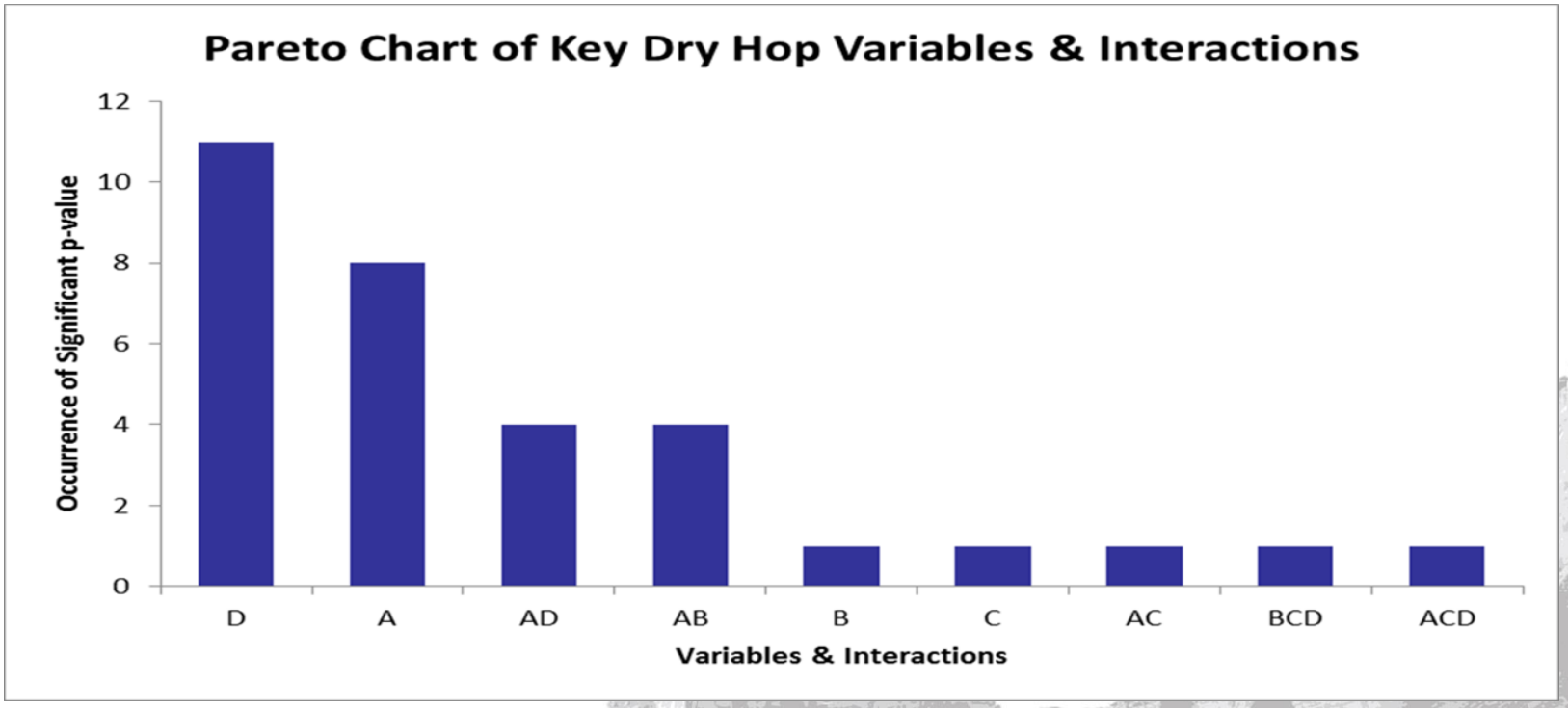
Data & Results

- Organized by a pareto of coefficients. Red = p ≤0.05
- Identifies the significant interactions among variables.
- Significant interactions elucidated by p-values of ≤0.05.



Data & Results

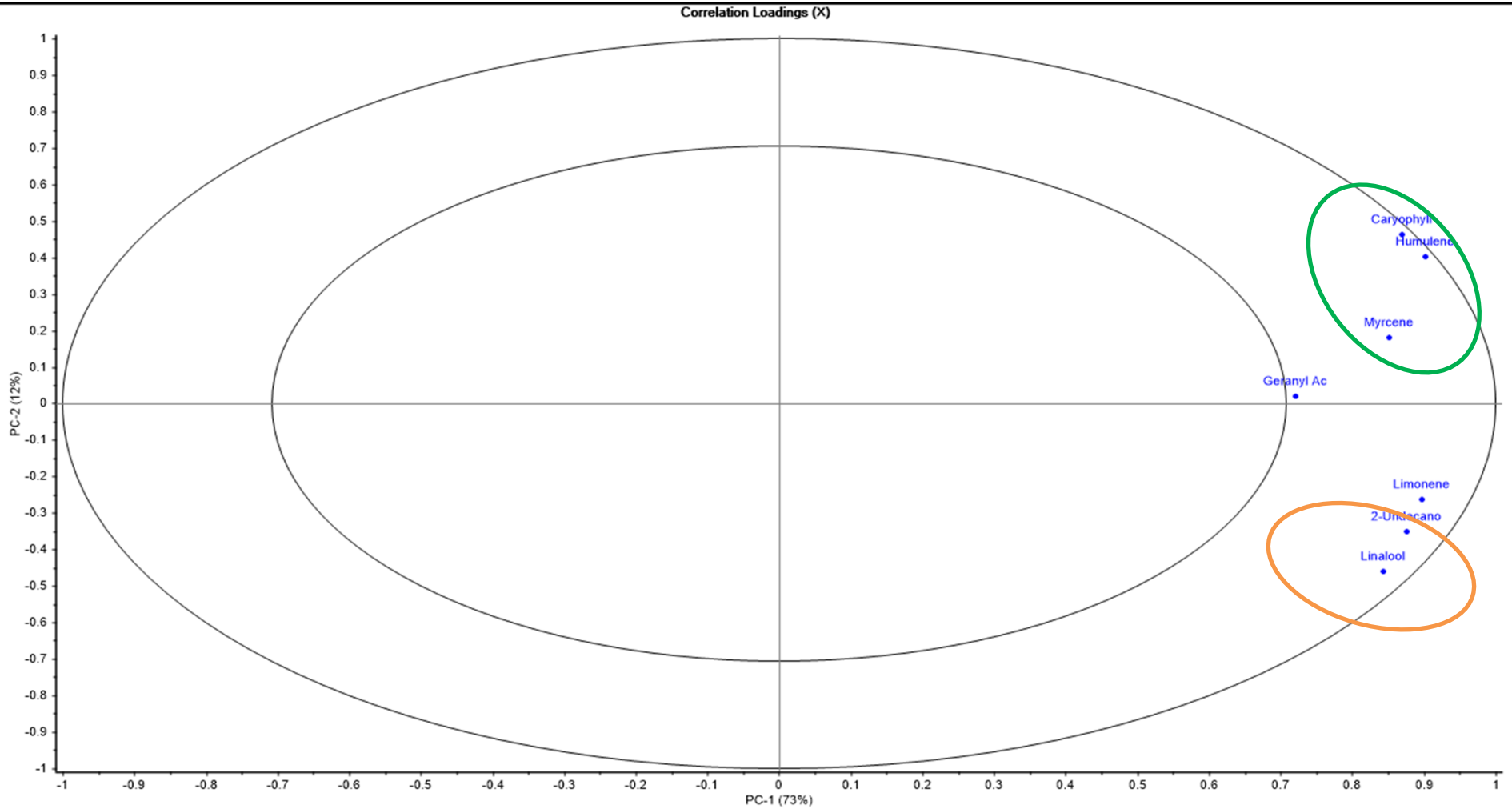
- A ‘Pareto of Pareto Charts’ (p-values ≤0.05) was used to pull all data together.
- Dosing Rate & Temperature, individually or together, represent the most significant interactions.
- ABV% less significant, and pellet type not a large influencing factor.



- A = Temperature; B = ABV%; C = Pellet Type; D = Dosing Rate.

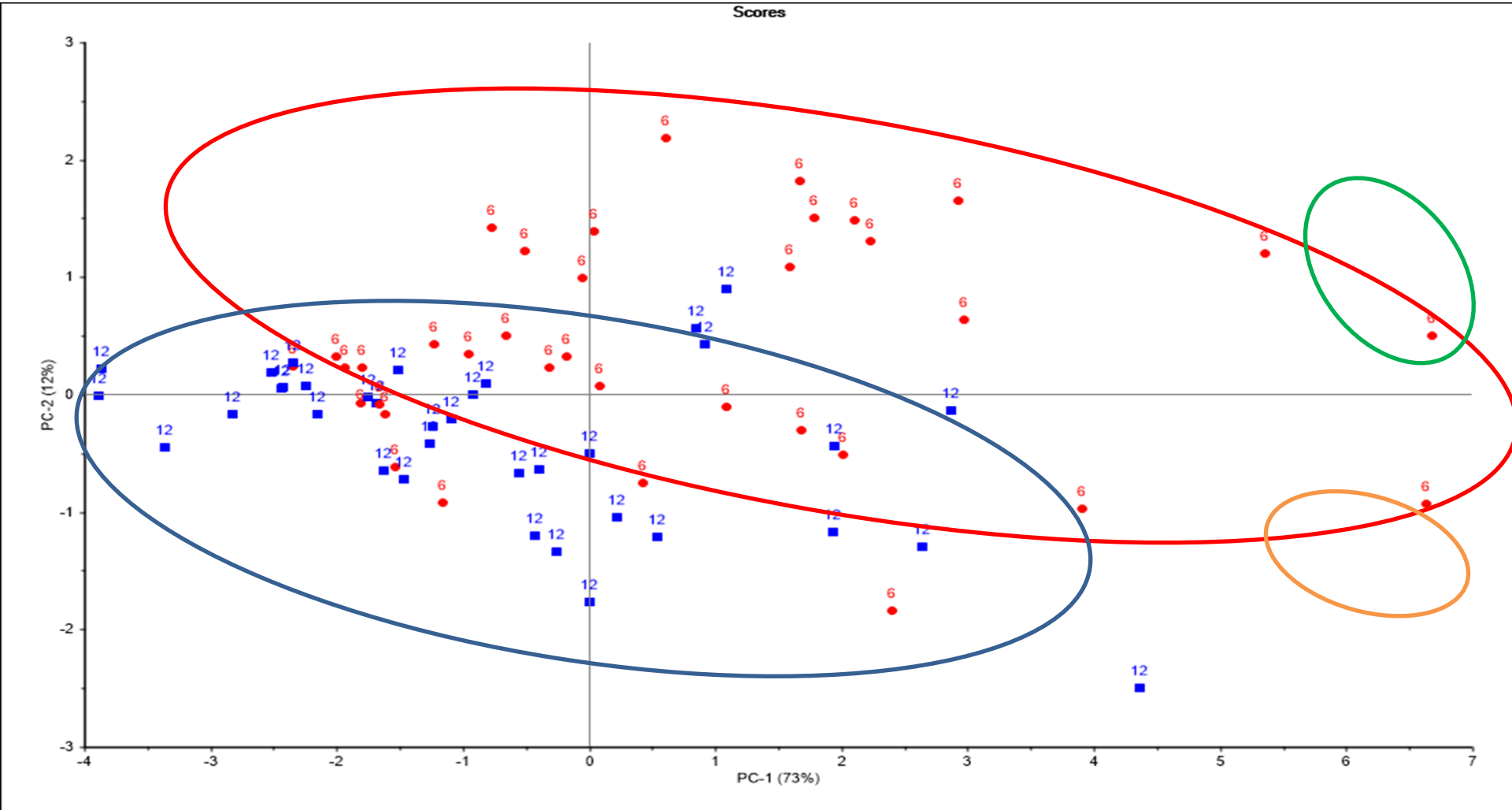
Principle Component Analysis (PCA)

Attribute Correlation Loadings: PC2 Upper vs. Lower Quadrants



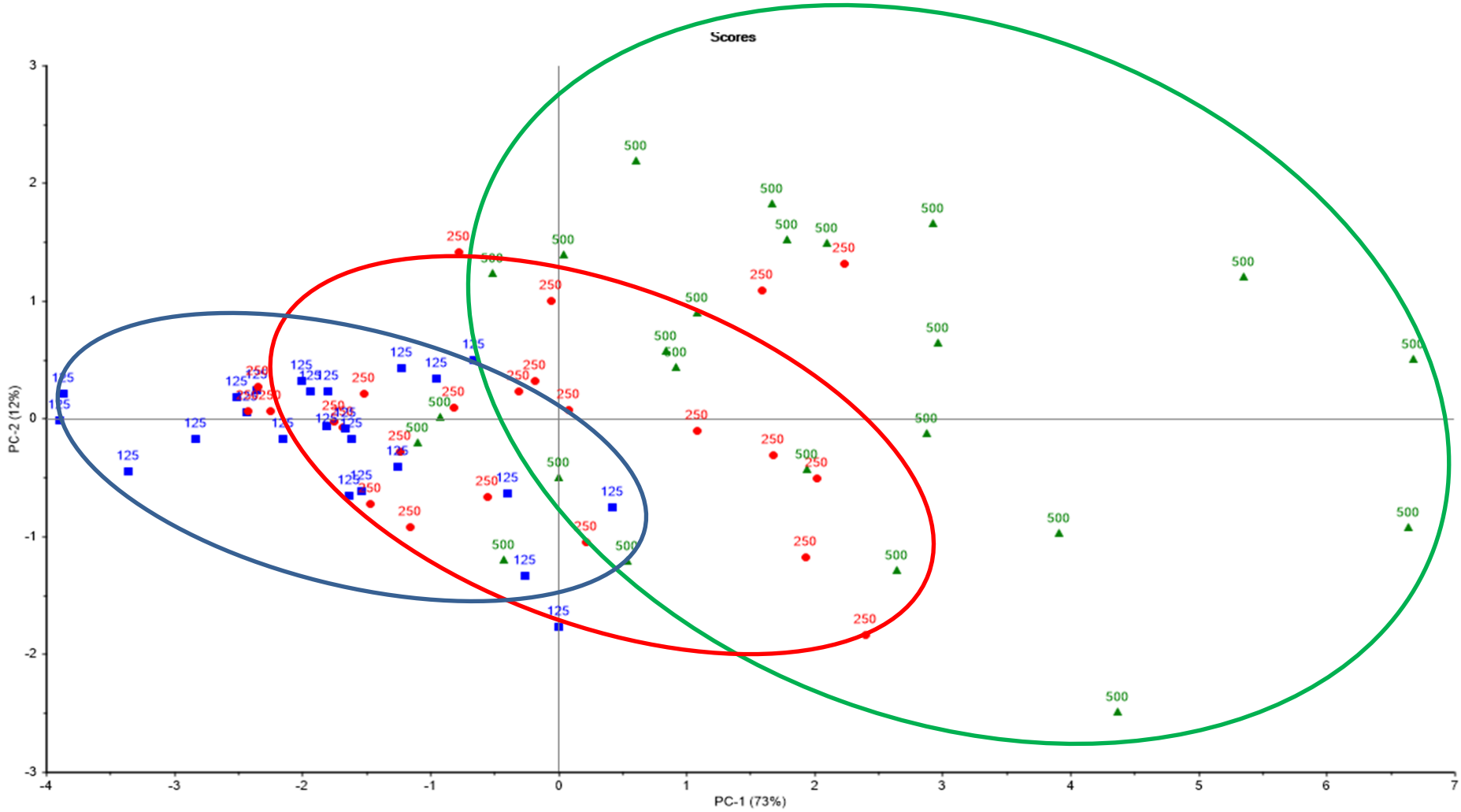
PCA: Beer Temperature

This separation suggests that compound loadings in the upper quadrants (green: myrcene, humulene, caryophyllene) are better extracted and/or retained at lower temperatures. While samples treated at 12C are better characterized by those hop aroma compounds in the lower quadrants (linalool).



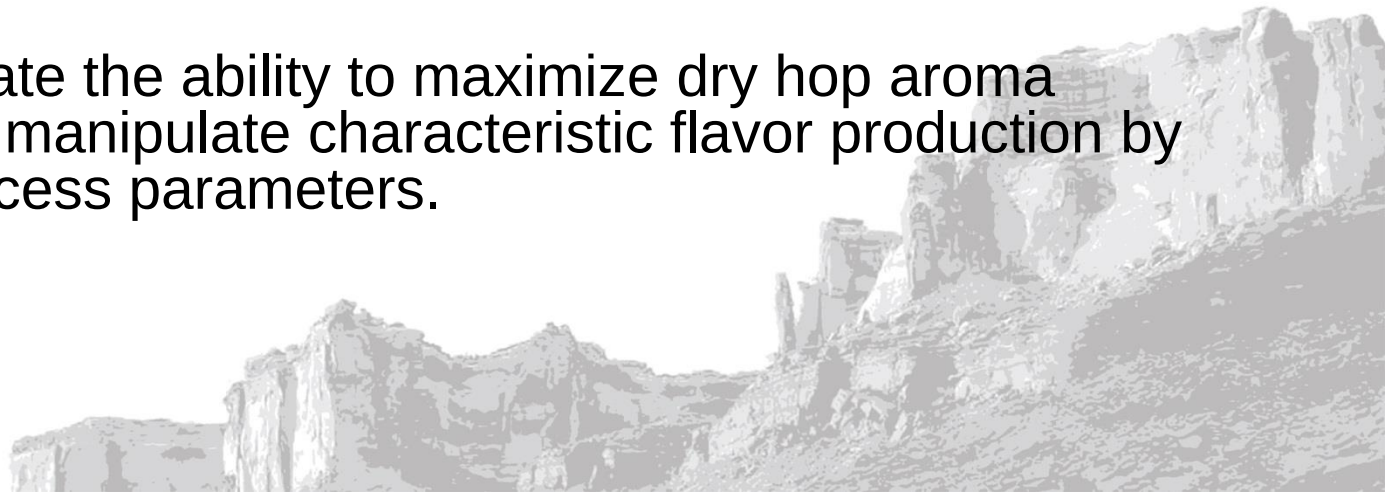
PCA: Hop Dosing Rate

Separation is evident, but not linear according to dosing rate!



Conclusions & Opportunities

- Hop dosing rate and beer temperature were the key factors influencing aroma compound concentration in this study.
- Beer alcohol concentration and hop pellet type had minor influences over aroma compound concentration in beer.
- Are the same results seen in a practical environment and are they repeatable?
  - Further investigation needed on a production scale.
- Results indicate the ability to maximize dry hop aroma potential and manipulate characteristic flavor production by changing process parameters.



Acknowledgements

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Questions?