Science of Hop Quality Testing
Wisconsin Quality 2019

Hop Production for the Wisconsin Craft Brew Industry

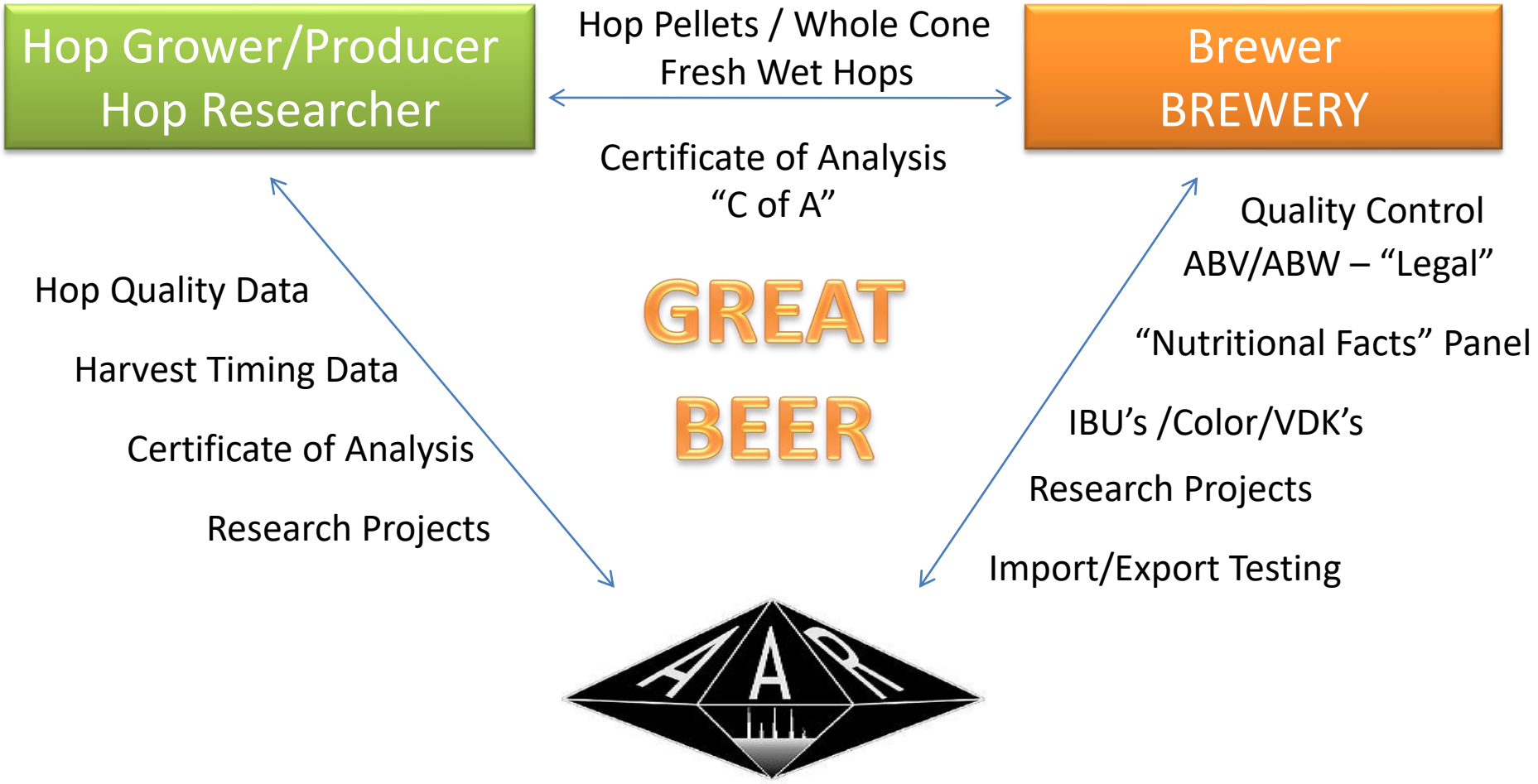
11th Annual Seminar

Zach Lilla

TTB Certified Chemist

Extension
UNIVERSITY OF WISCONSIN-MADISON

Role of AAR Lab



Hop Quality Indicators

- Alpha/Beta Acids (**Bitterness**)
- %Cohumulone (**Bitterness**)
- mL/100g Oil Content (**Aroma**)
- Oil Profile (**Aroma**)
- HSI – Hop Storage Index
- Moisture

YOUR PRODUCT IS:
BITTERNESS
& AROMA!

How do we achieve “Quality”

MOST CRITICAL

LEAST CRITICAL

- Harvest Timing
- Drying
- Pelletizing
- Storage
- Packaging

Goal is to meet the varietal specifications

AAR Hop Quality Report

		Typical Range	
% Moisture	9.4	8 - 12%	✓
Total Oil ml/100g @ 10%	1.66	1.0 - 2.5 mL	✓
cohumulone	29.6	27 - 31%	✓
Alpha Acids @ 10%	9.81	11.5 - 15%	↓
Beta Acids @ 10%	2.54	3.0 - 4.0%	↓

Chinook

Harvest Timing
When do I Pick?

- Early Harvest
  - Low alpha
  - Low oil
  - Grassy
  - Very Green

↓ $ Per #

EACH VARIETY HAS A DIFFERENT "SWEET SPOT"

- Late Harvest
  - Low alpha
  - Higher Oil
  - High HSI
  - Oxidized
  - Brown

↓ $ Per #

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When to Pick?

Science

- AAR Pre-Harvest Test
  - Dry Matter
  - Alpha/Beta Content
  - %Cohumulone
  - Total Oil Content
  - HSI?

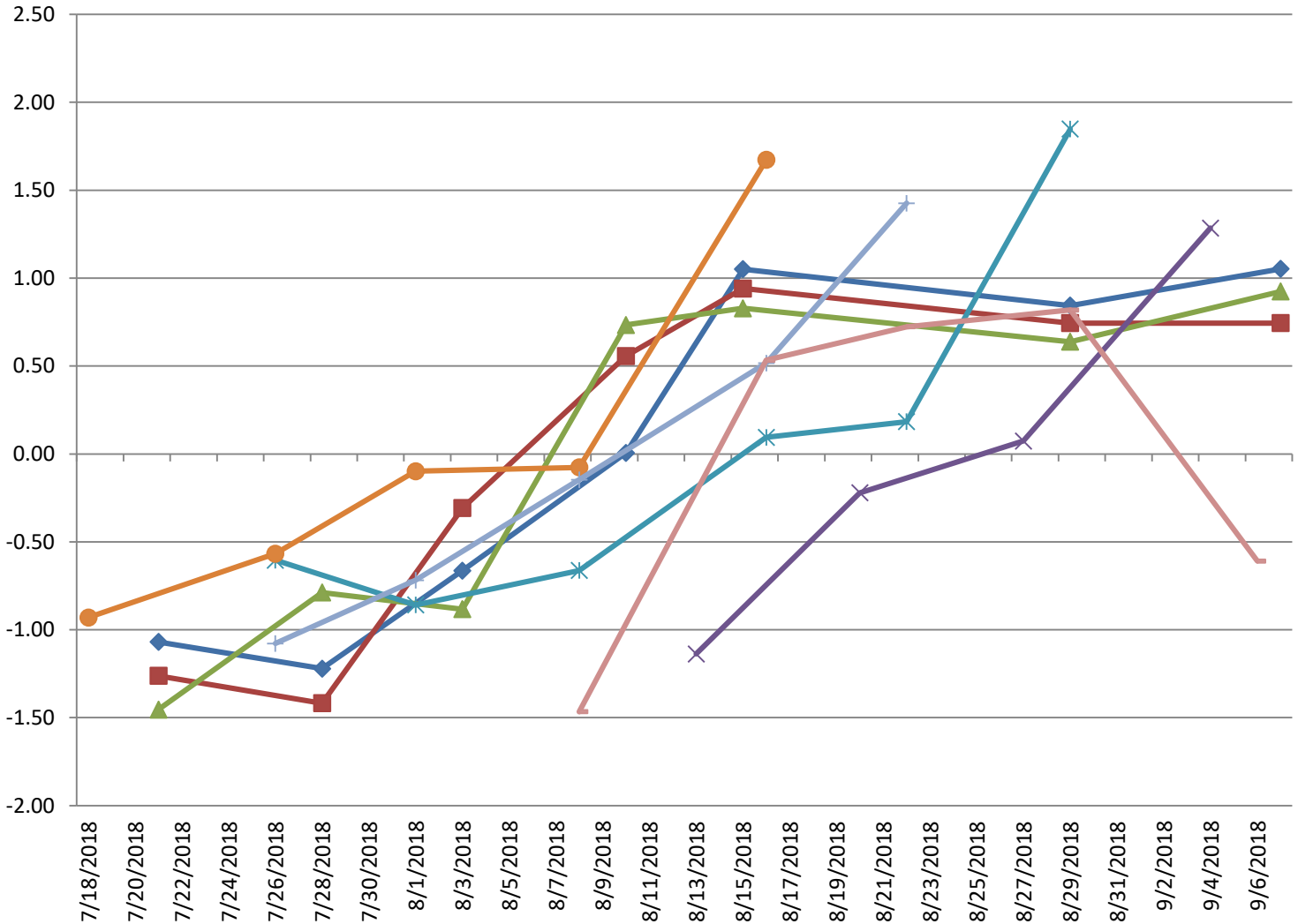
Art

- Lupulin Color
  "school bus yellow"
- Smell
- Experience
- Microscopy
  "Lupulin Gland Exam"

Let's Look at AAR Pre-Harvest Testing

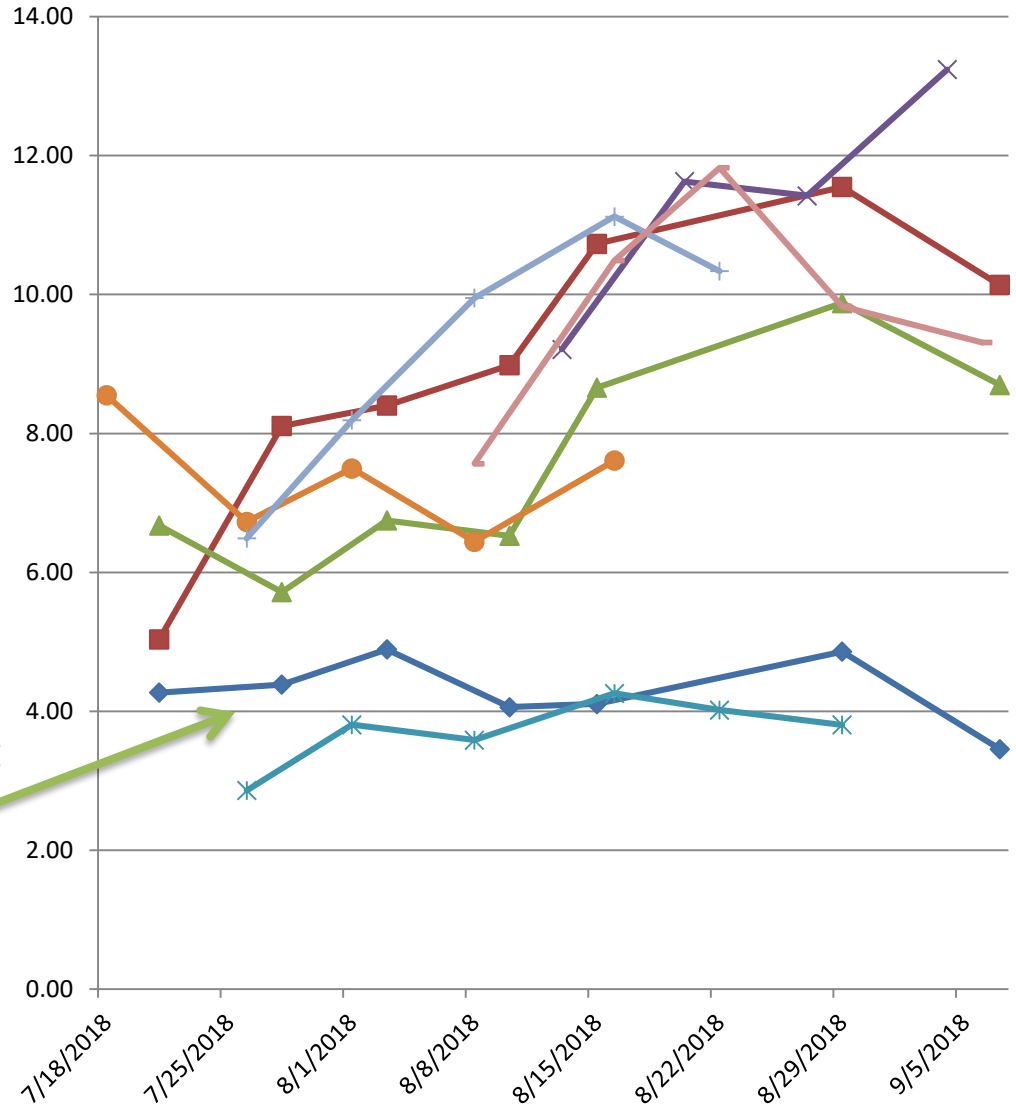
Dry Matter

Pre-Harvest Testing



Alpha Acid Content

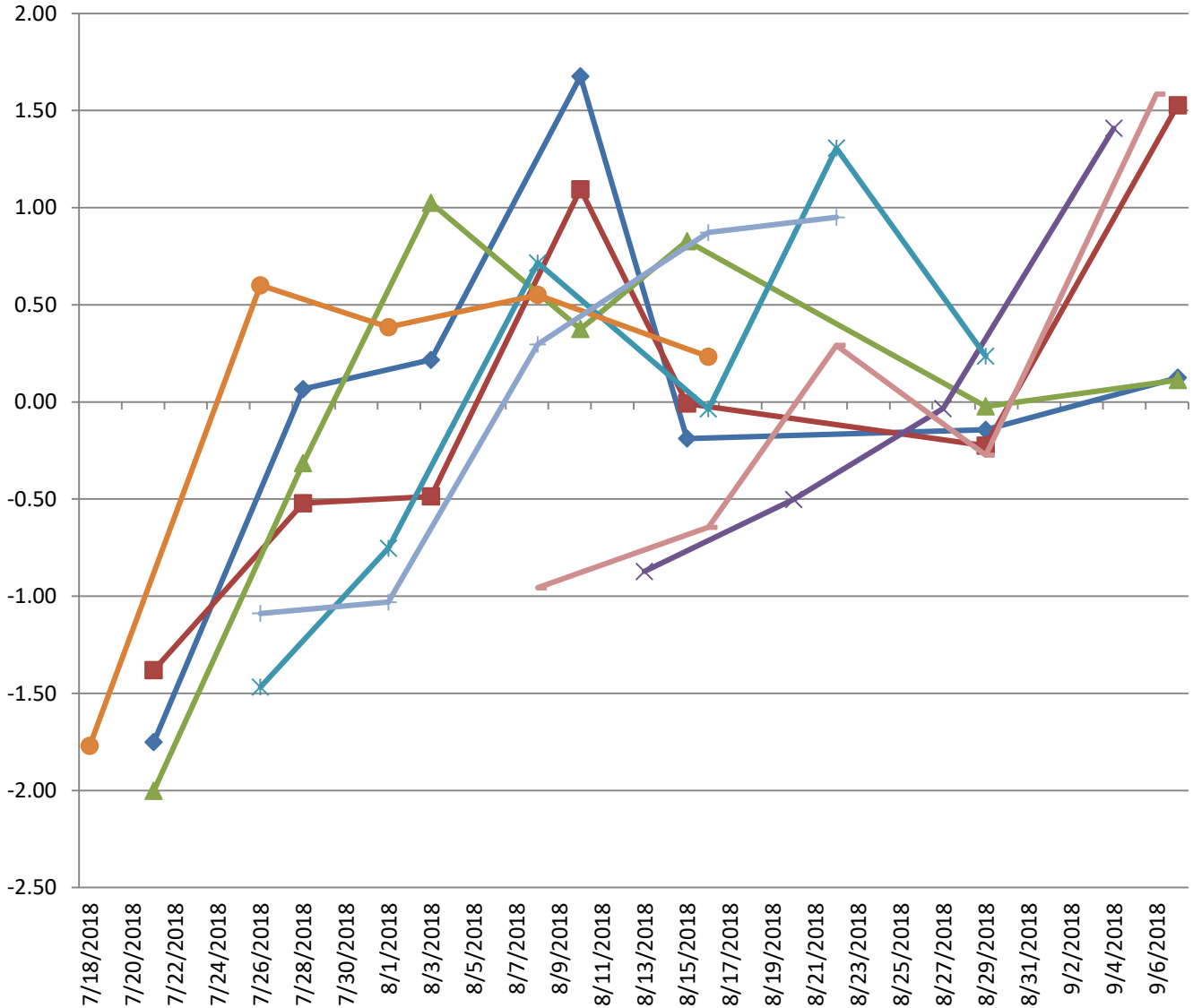
Pre-Harvest Testing



Some Varieties Won't "Follow the Rules"

Cohumulone

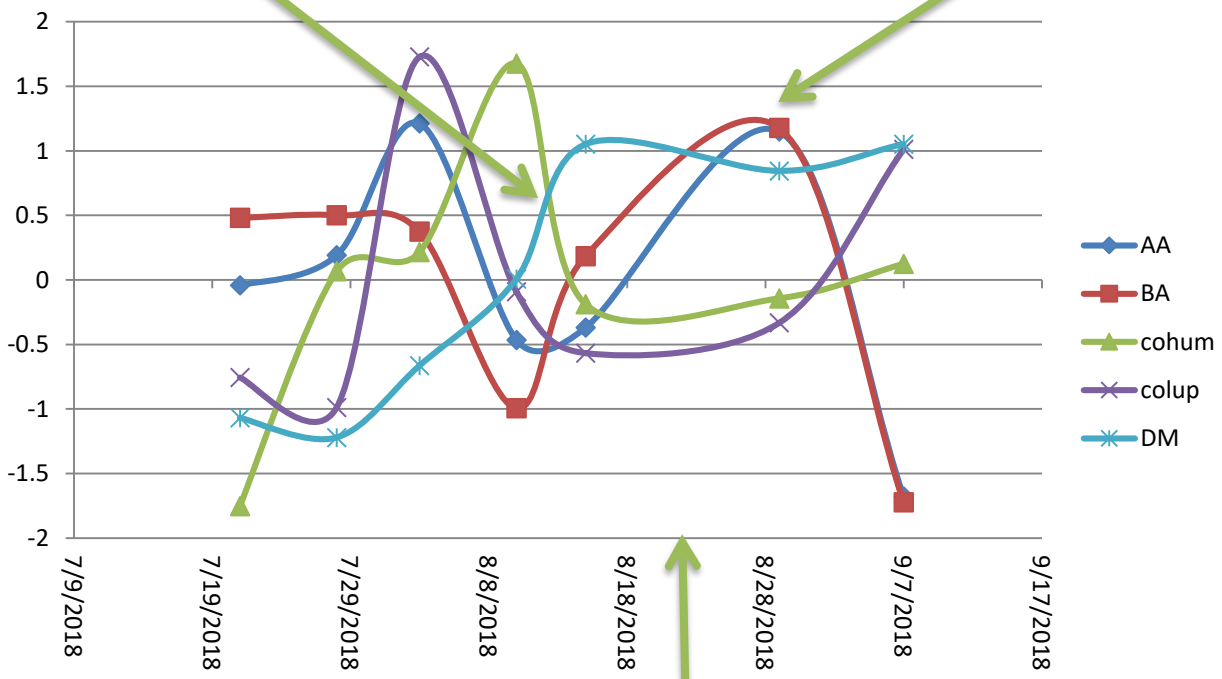
Pre-Harvest Testing



Which Harvest Indicator is Best?

Dry Matter "Bump"

Alpha Acid "Apex"



2018 Pre-Harvest Profile - Chinook

AAR Pre-Harvest Test Results 8/20

Chinook	Typical Ranges
% Alpha	11.5 - 15%
% Beta	3 - 4%
Cohumulone	27 - 31%
Total Oil	1 - 2.5 mL

Calculations (Brewing Values @ 10% moisture)

	SPEC	HPLC
% Alpha	NT	**11.63**
% Beta	NT	3.24
Cohumulone		**26.1**
Total Oil	**NT**	mL/100g

AAR Pre-Harvest Dry Matter 23.4%

Lets Break Down the Test Results

#1 – Dry Matter in Range? (23-25%) **YES!**

Dry Matter 23.4%

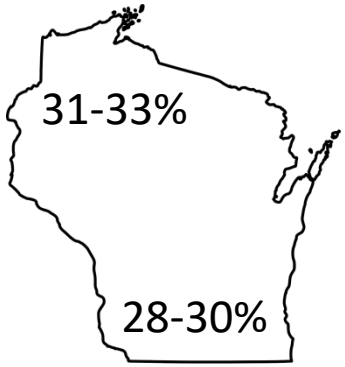
#2 – Alpha in Range? **YES!**

Calculations (Brewing Values @ 10% moisture)

Chinook	Typical Ranges		SPEC	HPLC
% Alpha	11.5 - 15%	**% Alpha**	NT	**11.63**
% Beta	3 - 4%	% Beta	NT	3.24
Cohumulone	27 - 31%	**Cohumulone**		**26.1**
Total Oil	1 - 2.5 mL	**Total Oil**	**NT**	mL/100g

#3 – Cohumulone in Range? **NO!**

Note: %Cohumulone is Latitude (photoperiod) Based.



Target %Cohumulone is based on your local for all varieties.

It's low, and we know Cohumulone rises, so this tells us % Alpha may be on the way up.

Pre-Harvest vs Post Harvest

Wet Fresh Hops

Var. - % Alpha / % Beta

- TP - 12.03/3.63
- CHI - 11.63/3.24
- NUG - 13.54/4.42
- Zeus - 7.87/3.01
- CAS - 5.46/5.75
- CAS - 8.54/6.18

Pelletized Hops

Var. - % Alpha / % Beta

- TP - 11.34/3.79
- CHI - 11.29/3.66
- NUG - 14.78/4.23
- Zeus - 8.25/3.20
- CAS - 5.46/6.18
- CAS - 9.72/5.85

Hundreds of examples that show similar performance……

Science works!

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AAR

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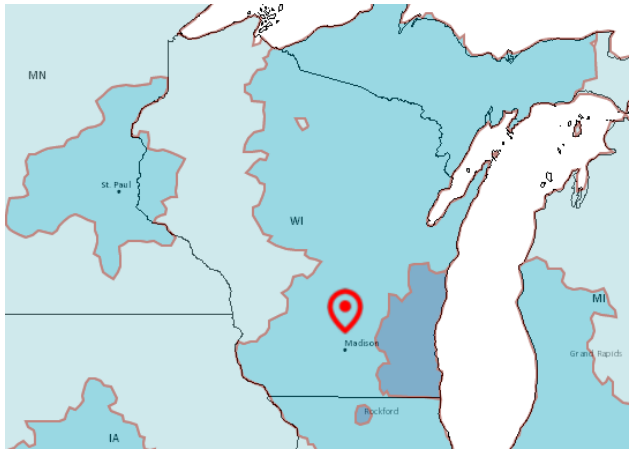
Tips – Sending Fresh/Wet Samples

- Box
  - Envelopes cause condensation
- Don't vacuum
  - crushes – cells break
- Overnight or Priority 2-Day (USPS)
- SPEE-DEE (good rates)

- Pick a representative sample – not just the "good ones"
- NO Ice or cold packs
  -causes condensation



USPS Priority Shipping Map

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Post Harvest
"Preserve What You Picked"

What to Monitor

- Moisture
- HSI
- Alpha/Beta (Bitterness)
- Oil (Aroma)

Do your hops meet the varietal specs, will they meet the Brewer's expectations?

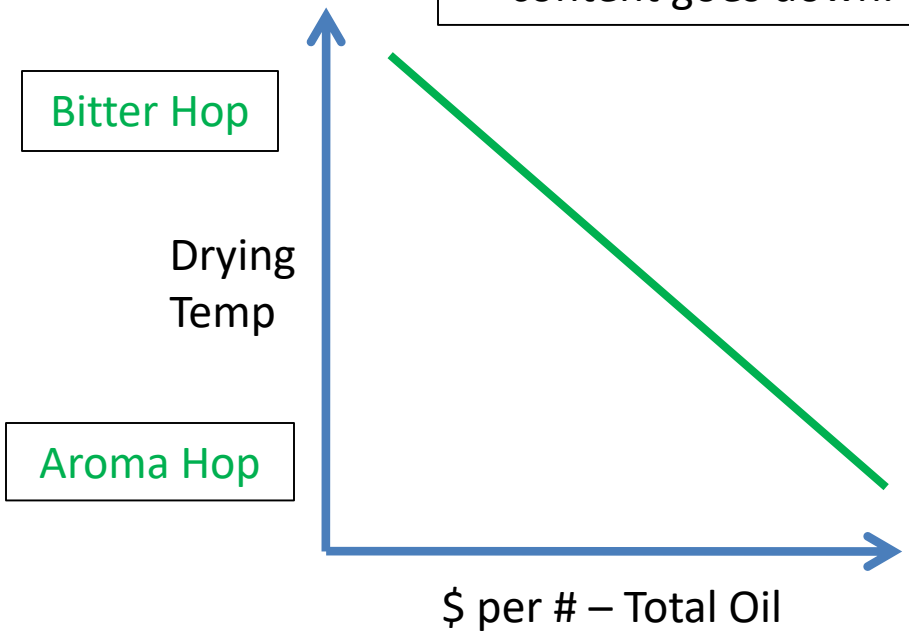
Did processing lower Hop Quality or Aroma Quality (AQ)?

		Typical Range	
% Moisture	9.4	8 - 12%	✓
Total Oil ml/100g @ 10%	1.66	1.0 - 2.5 mL	✓
cohumulone	29.6	27 - 31%	✓
Alpha Acids @ 10%	9.81	11.5 - 15%	↓
Beta Acids @ 10%	2.54	3.0 - 4.0%	↓

Post Harvest
% Moisture

- Goal 8 – 12%
- <8% – shatter cones/pellets won't break up
- >12% - could lead to storage issues/mold musty aroma

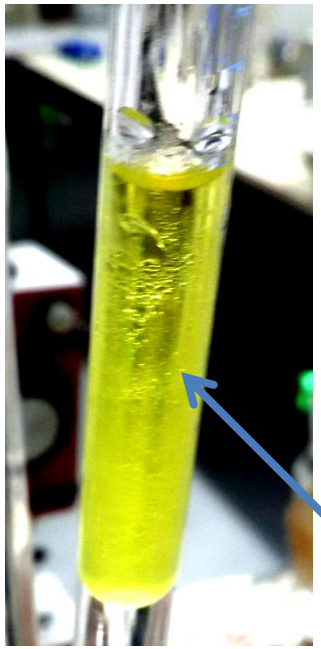
As Drying Temp goes up, price per pound & oil content goes down.



AAR – Determines moisture/dry matter by ASBC Hops 4C

Post Harvest
HSI (Hop Storage Index)

Very Fresh	**<0.25**
Fresh Whole cone/Pellets	**<0.30**
Stored Hops	**0.31 – 0.40**
Aged hops	**0.40 – 0.50**
Old Hops	**>0.50**



AAR - Spectroscopy – monitor absorbing wavelengths of hop acids – ratio of oxidized vs non-oxidized acids

ASBC – Hops 12

Old Hops (Oxidized Oil)

Post Harvest
Alpha/Beta - cohumulone

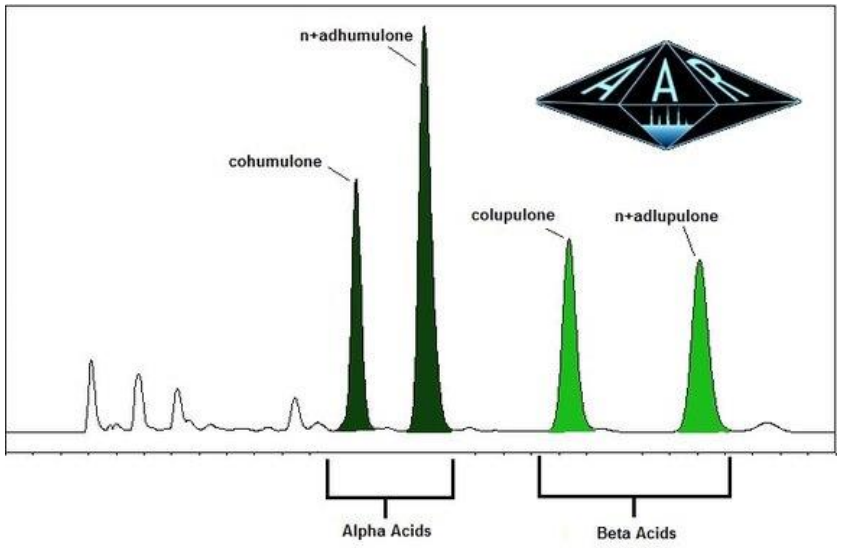
- Maintain Varietal Specs

  -yield similar bitterness in brews

  -Technical Brewers – provide accurate alpha data, adjust additions

Proof of quality!

Price per pound. $



Cascade Hops α & β Acids Analysis by HPLC

AAR - Analyzes whole hops or pellets by HPLC
ASBC Hops-14

Post Harvest Oil (Aroma)

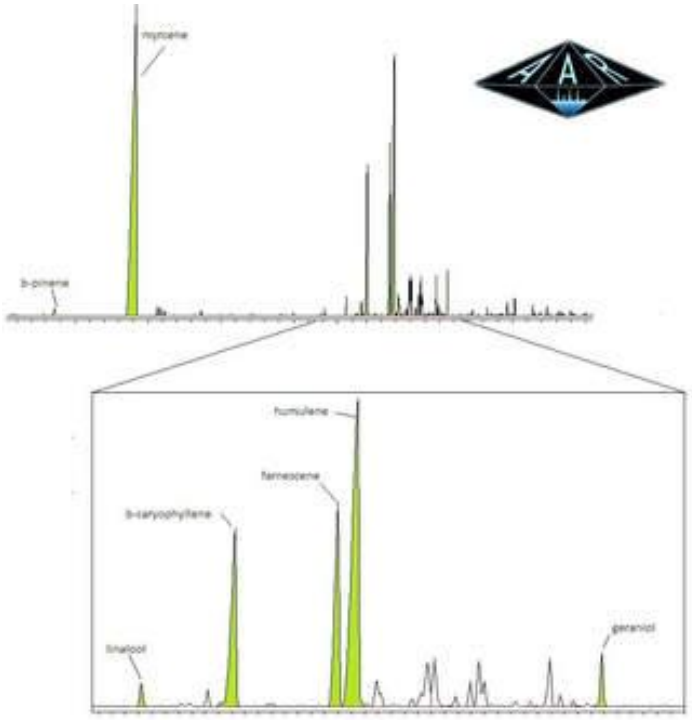
- Maintain Varietal Specs
  - Total Oil Content
  - Profile (Fingerprint)

Why?

Impart similar aroma/flavor in brews

Provide tech Brewers with accurate dosing adjustments for dry hopping, late/first additions

- AAR - Steam Distillation
  - Total Oil (mL/100g)
  - Analyze Oil by GC-FID



Essential Oil Profile of Cascade Hops by GC-FID

Post Harvest
Aroma Quality (AQ)

- Typical Oil Profile Data
  - % Area
  - Confusing
  - Not Quantitative
- Useful?

- AAR – Aroma Quality
  - % Area
  - mg/mL
  - mg/100g
- -7 most common compounds

Hop Oil Composition Analysis by % Area and mg/100g

	Cascade Pellet A		Cascade Pellet B	
	% area	mg/100g	% area	mg/100g
b-Pinene	0.711%	16.0	0.292%	1.92
Myrcene	60.5%	1360	26.0%	171
Linalool	0.548%	12.3	0.584%	3.83
Caryophyllene	5.90%	133	12.2%	80.6
Farnesene	6.15%	138	11.6%	76.0
Humulene	11.9%	268	27.3%	180
Geraniol	0.253%	5.69	0.123%	0.806

We know the oil inputs! NEW

- Adjust recipe based on data (yield consistent brews)
- Blends?

Aroma Quality (AQ)

AROMA QUALITY (AQ) — **Chinook**

	% Area		
B-Pinene	0.39	0.20 - 0.60 %	✓
Myrcene	29.29	20.00 - 30.00 %	✓
Linalool	1.16	0.30 - 0.60 %	↑
Caryophyllene	10.49	8.00 - 12.00 %	✓
Farnesene	0.72	0.01 - 1.00 %	✓
Humulene	20.17	18.00 - 24.00 %	✓
Geraniol	0.77	0.50 - 1.00 %	✓
	mg/mL		
B-Pinene	4.69	2.0 - 6.0	✓
Myrcene	350.66	200 - 300	↑
Linalool	13.92	3.0 - 6.0	↑
Caryophyllene	125.53	80 - 120	↑
Farnesene	8.66	0.1 - 10	✓
Humulene	241.46	180 - 240	↑
Geraniol	9.23	5.0 - 10.0	✓
	mg/100g @ 10% Moisture		
B-Pinene	7.80	2.0 - 15.0	✓
Myrcene	582.91	200 - 750	✓
Linalool	23.13	3.0 - 15.0	↑
Caryophyllene	208.67	80 - 300	✓
Farnesene	14.40	0.1 - 25	✓
Humulene	401.38	180 - 600	✓
Geraniol	15.34	5.0 - 25.0	✓

- Convey proof of quality indicators to your customer
- Tweak drying & processing to deliver the product Brewer's are looking for.
- Develop aroma hop markets
- Blends/Replacements
- Point out unique qualities of the hop

Do your hops meet the varietal expectations for Aroma??

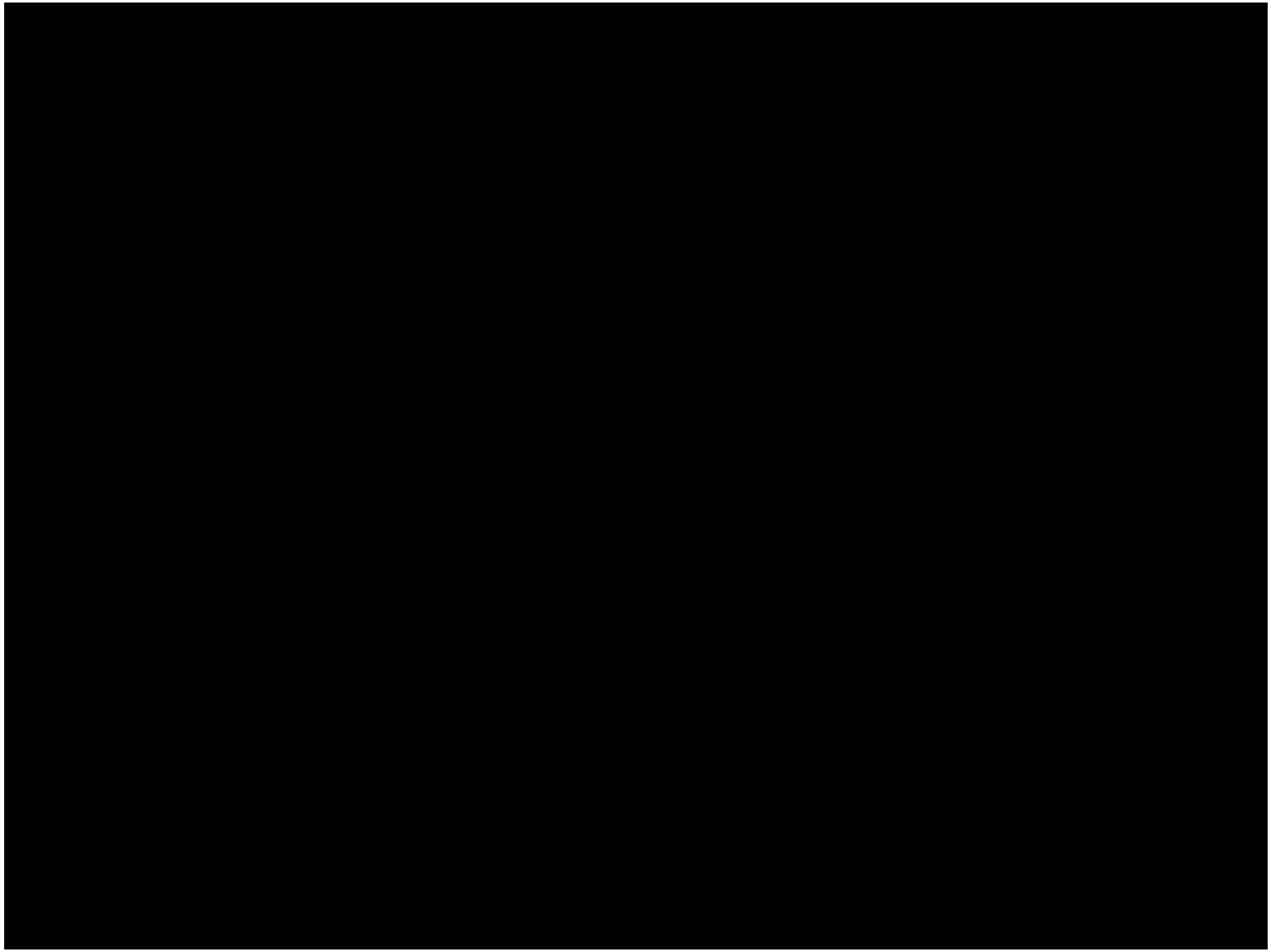
Are We Different?
Quest for the Proof of “Terroir”

- Where’s the data?
- Challenges
  - Nothing is the same
    dryers, pickers, pelletizers
  - No standard test methods
  - Not enough data

Not Easily Answered……

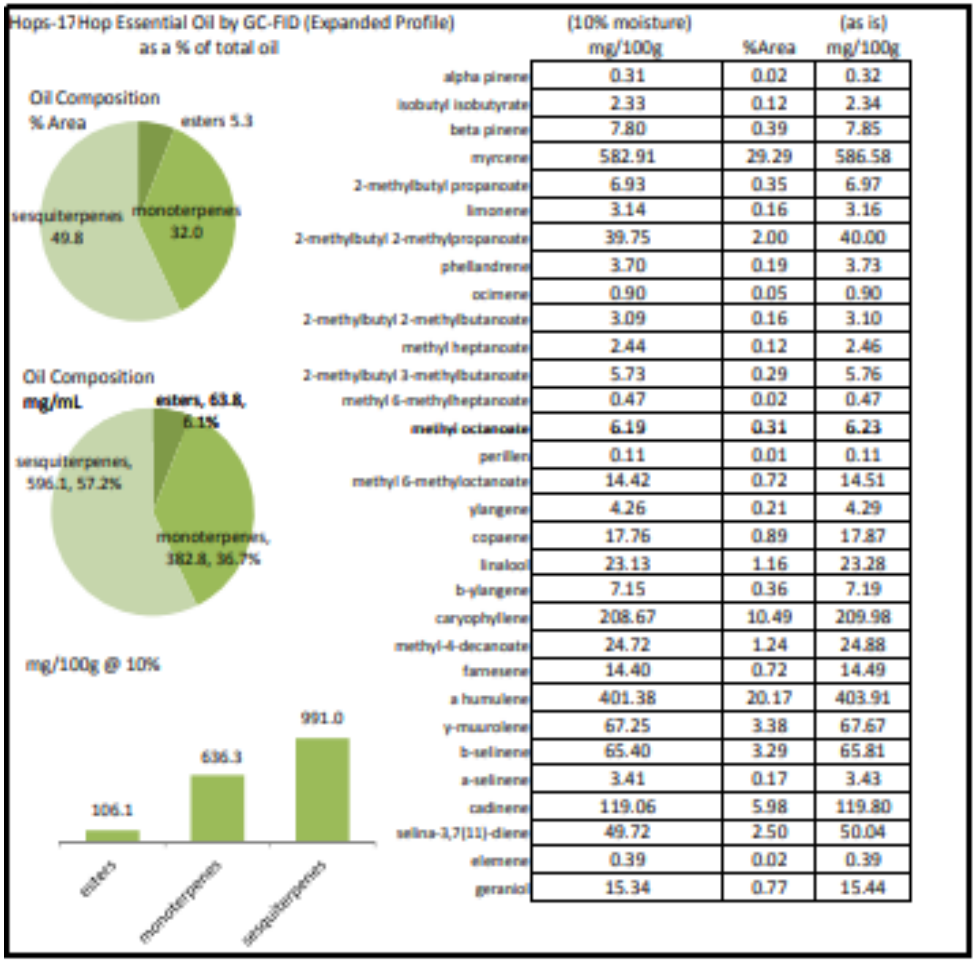
AAR Lab Instruments
“Fighting The War on Terroir”

HS-SPME-GCMS Hop Volatiles



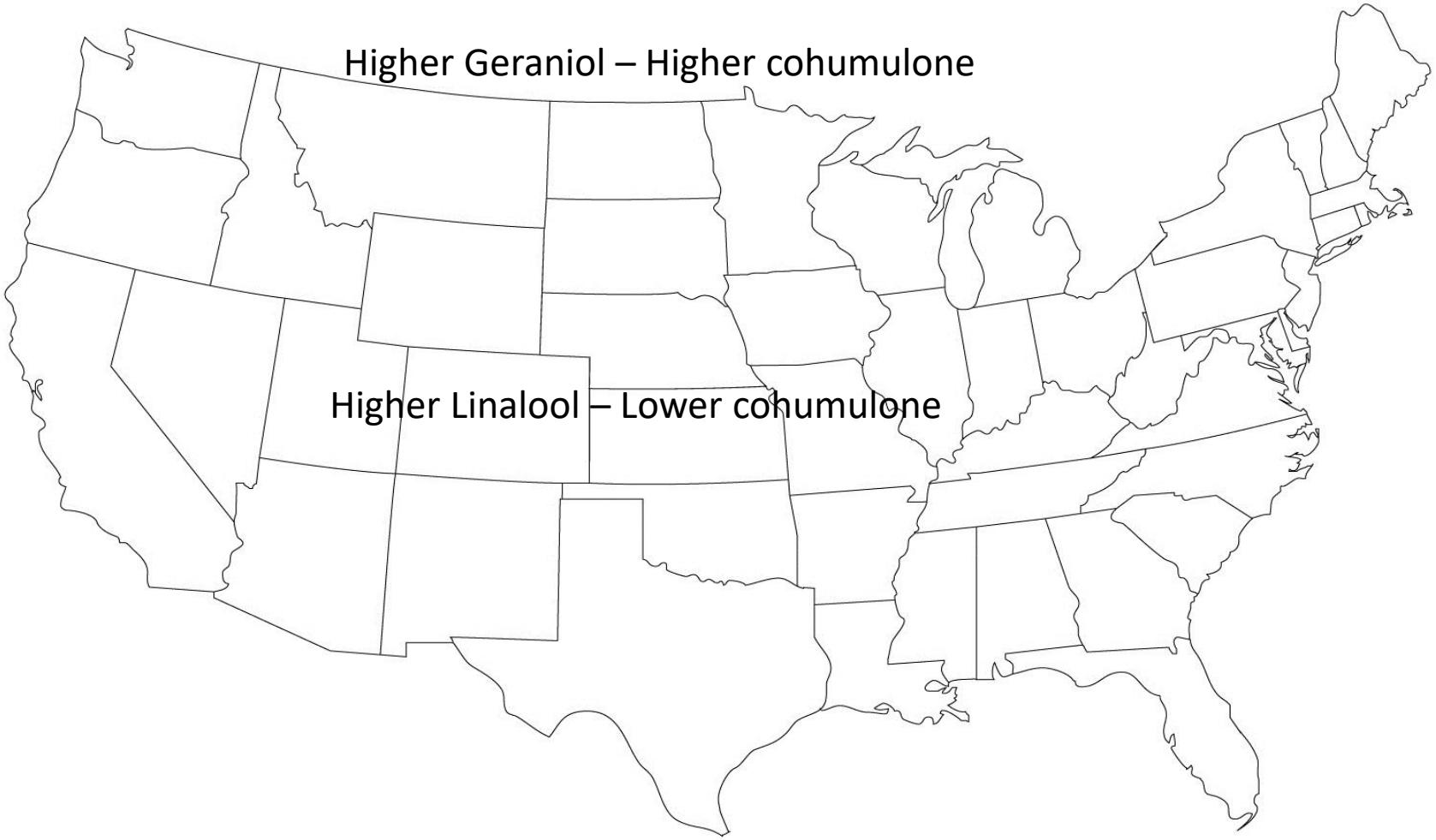
AAR – Comprehensive Profile

- Total Oil Content – mg/100g
- AQ – 7 compounds
- Extended Profile – 32 compounds
- Quantitative Oil Profile
  - % Area
  - mg/mL
  - mg/100g
- Alpha/Beta – cohum/colup
- HSI
- Breakdown
  - esters – (Fruity)
  - monoterpenes – (Flowery)
  - sesquiterpenes – (Herb/Spice)



	(10% moisture) mg/100g	%Area	(as is) mg/100g
alpha pinene	0.31	0.02	0.32
isobutyl isobutyrate	2.33	0.12	2.34
beta pinene	7.80	0.39	7.85
myrcene	582.91	29.29	586.58
2-methylbutyl propanoate	6.93	0.35	6.97
limonene	3.14	0.16	3.16
2-methylbutyl 2-methylpropanoate	39.75	2.00	40.00
phellandrene	3.70	0.19	3.73
ocimene	0.90	0.05	0.90
2-methylbutyl 2-methylbutanoate	3.09	0.16	3.10
methyl heptanoate	2.44	0.12	2.46
2-methylbutyl 3-methylbutanoate	5.73	0.29	5.76
methyl 6-methylheptanoate	0.47	0.02	0.47
methyl octanoate	**6.19**	**0.31**	**6.23**
perillen	0.11	0.01	0.11
methyl 6-methyloctanoate	14.42	0.72	14.51
ylangene	4.26	0.21	4.29
copaene	17.76	0.89	17.87
linalool	23.13	1.16	23.28
b-ylangene	7.15	0.36	7.19
caryophyllene	208.67	10.49	209.98
methyl-4-decanoate	24.72	1.24	24.88
farnesene	14.40	0.72	14.49
a humulene	401.38	20.17	403.91
γ-muurolene	67.25	3.38	67.67
b-selinene	65.40	3.29	65.81
a-selinene	3.41	0.17	3.43
cadinene	119.06	5.98	119.80
selina-3,7(11)-diene	49.72	2.50	50.04
elemene	0.39	0.02	0.39
geraniol	15.34	0.77	15.44

Trends in the Data



Questions?

Thank you

2019 Wisconsin Report

Big jump in Aroma Hops, better drying methods? Harvest Timing? Equipment?

Alpha (Bittering Hops) – Hop Quality – Increased – 100% over 2018

Oil – Profile - (Aroma Hops) – Aroma Quality – Increased – 300% over 2018

Chinook, Magnum, Centennial – all time high alpha's & Oil – High alpha, High oil!