Malt Flavor Beyond the Kiln

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MSU Barley Breeding Program

Breeder:
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Quality Lab:
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Field Manager:
Greg Lutgen

2 PhD Students

1 Masters Student

9 Undergraduate Students

Hannah Turner

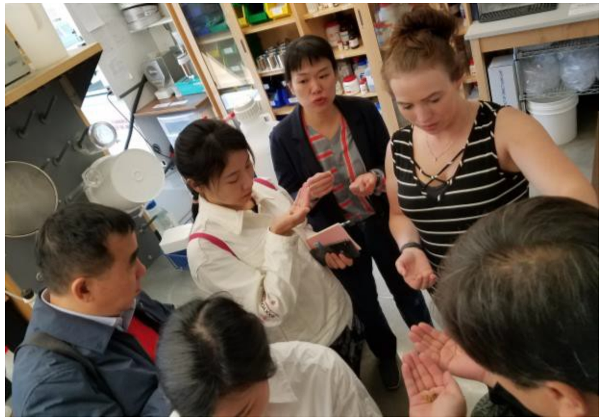
New Hampshire
Golf Course Management

BS 2014 – Plant Science
MS – 2016 – Plant Science

MSU Barley Breeding Program – 2016 to present
Craft Maltster's Guild BOD – 2018 to present
ASBC – Technical Committee - 2020 to present

Barley, Malt & Brewing Quality Lab

Research | Service | Education



Road Map

- Review: what you may already know about malt flavor
  – Kiln control over malt styles and flavor
  – Other known flavors from malt
- Less considered areas of malt flavor
  – Variety, malt modification, terroir
  – Research review and current studies – 10 studies
- Potential interplay of these aspects

Impact of Malt on Beer

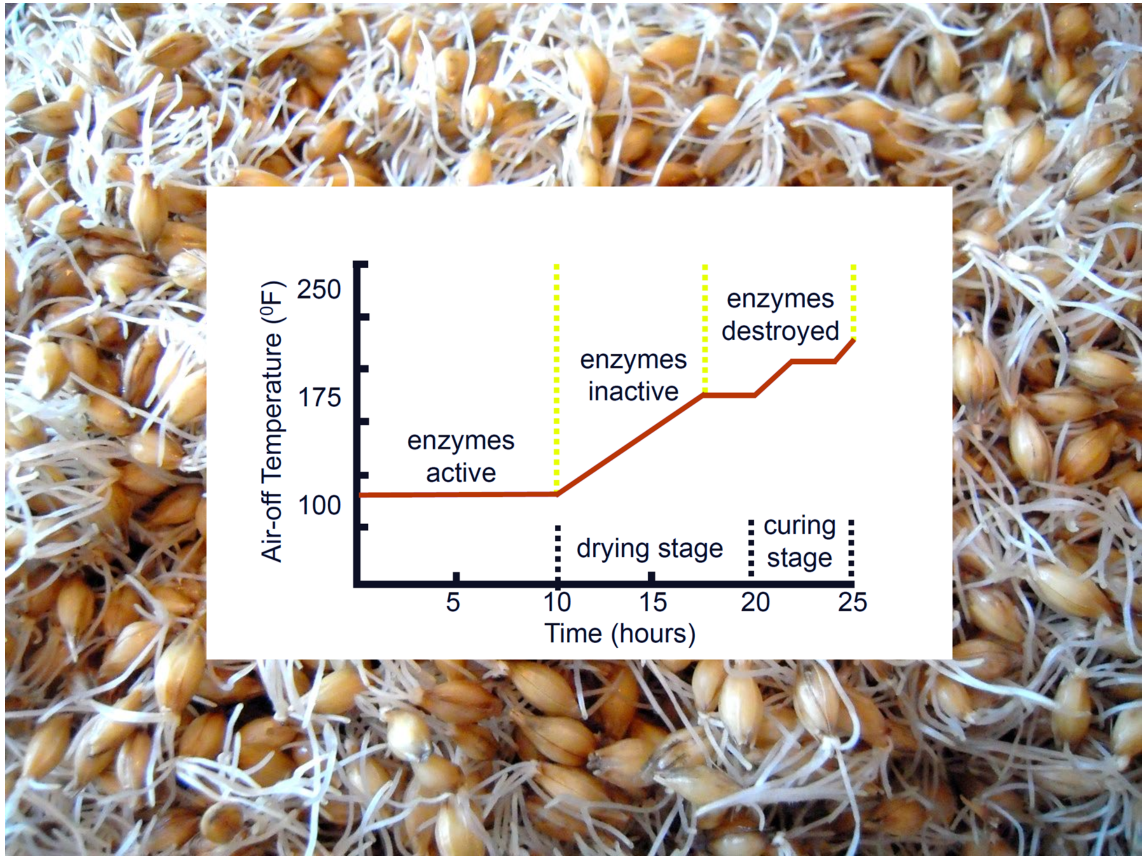
- Beer flavor/aroma
  - Kiln byproducts
  - Fermentation
  (malt is food for yeast)
    - Esters
    - Higher alcohols
    - Sulfurs
    - Acidity
  - Mouthfeel
  - Finishing gravity
  - Astringency

- Beer Aesthetics
  - Haze
  - Head retention
  - Color

- Brewery Efficiency
  -Lauter time
  -Brewhouse yield
  -Filter time

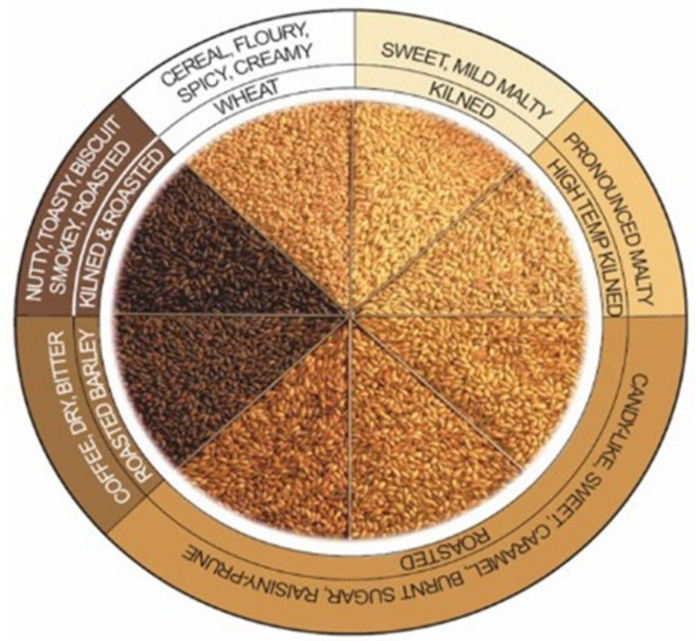
Purposes of Kilning

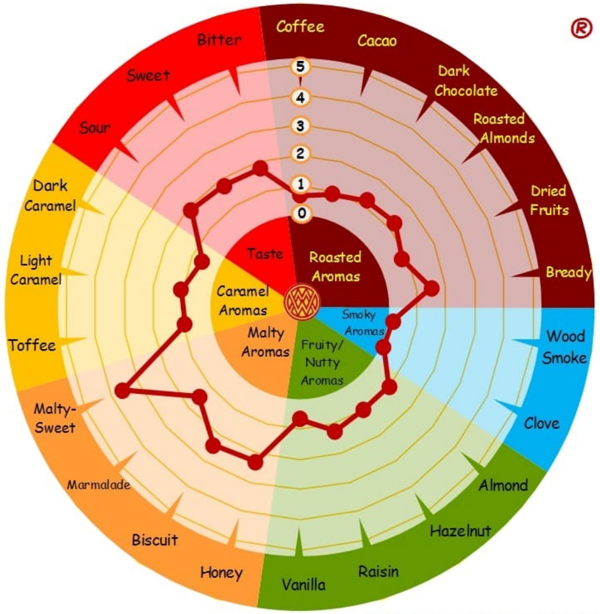
- Stops biochemical reactions
- Reduces moisture and weight
- Produces a stable product
- Makes malt crisp and friable
- Develops color, aroma, flavor



Chemistry of Kilning/Roasting – Browning Reactions

- Source of flavor/aroma and color compounds
  - Maillard browning
    - Sugars and amines
  - Caramelization
    - Sugar + high temps

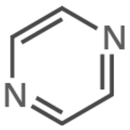




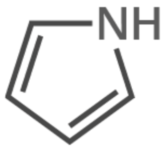
Maillard Browning

The Maillard reaction produces hundreds of products

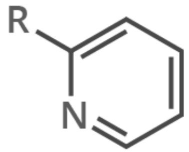
- Small subset of these contribute to flavor and aroma
- Melanoidins also formed: brown, polymeric substances contributing color



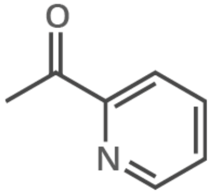
PYRAZINES
cooked
roasted
toasted



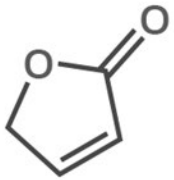
PYRROLES
cereal-like
nutty



ALKYLPYRIDINES
bitter
burnt
astringent

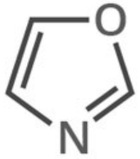


ACYLPYRIDINES
cracker-like
cereal



FURANONES
sweet
caramel
burnt

FURANS
meaty
burnt
caramel-like



OXAZOLES
green
nutty
sweet

THIOFENES
meaty
roasted

Caramelization

- Heated degradation/chemical interaction of sugars
- Requires higher moisture and temperature
  - typically occurs in a roaster rather than a kiln
- Sugars caramelize at different temperatures
  - Fructose: 110°C (230°F)
  - Galactose, Glucose, Sucrose: 160°C (320°F)
  - Maltose: 180°C (360°F)

Other known malt flavors: Off-Flavors

DMS: Sweetcorn, creamed corn, vegetal

- Comes from a sulfur-based organic compound produced in germinating grain
- Six row lager malts and pilsner malts have the highest levels
  - Adjuncts like corn are also high.
- DMS can also come from wild yeast or bacterial contamination during fermentation

Grainy/Husk Like flavors

- Caused by isobutyraldehyde in malt (also some other aldehydes)
- High levels in fresh malt
- High husk to endosperm ratio can promote

Staling

- Allowing malt to gain moisture promotes staling
- Above 6% moisture malt is at risk for mold growth

Kilning and off-flavors are well known and control is understood

Take Homes for Malt Off-Flavor Control

- Know you moisture – don’t purchase malt over 6%
- Store malt in cool dry conditions – avoid gaining moisture over 6%
- Fresh malt is best, but ensure it has cured a few weeks prior to use
- Treat your malt gently – broken kernels uptake moisture more readily
- Don’t over-crush your malt
- Mash and sparge conscientiously (temps, don’t over sparge)

Innovative Unique Craft Malts To Look For!

- Smoked malts
  - Fruit: Pear, apple, cherry, mulberry, persimmon, plum, apricot
  - Wood: hickory, walnut, red oak, white oak, beech, pecan, lilac, peat
  - Imported woods: Lemon, orange, coffee, pimento, olive, mesquite
  - Barrels: cabernet, French oak, bourbon, tabasco, rum
  - Herbs: Lemon balm, sage, lavender, spearmint, peppermint, tarragon

  Check out sugarcreekmalt.com!

- Barrel aged malts -> image: Rootshootmalting.com

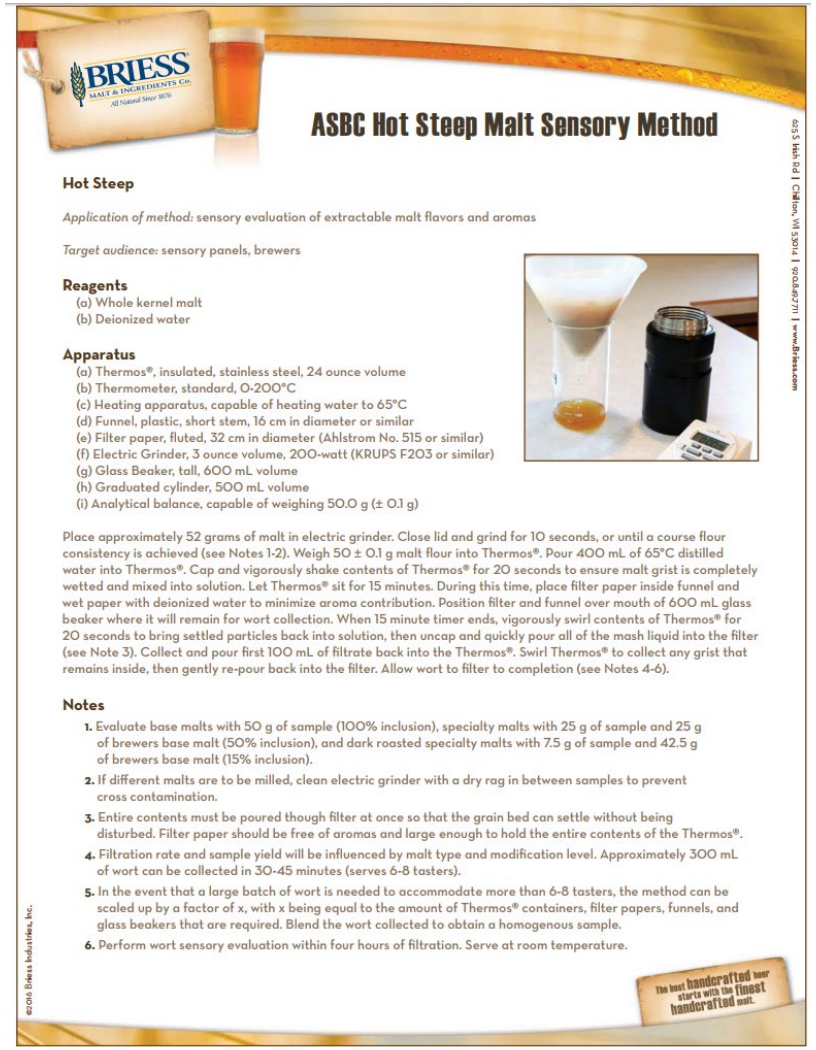
Down the Rabbit Hole

Variety, Modification, Terroir

Does Variety Impact Flavor?

Hot Steep Method

- Method for making a “malt tea” for malt sensory evaluation
- Method approved by ASBC in 2017
- Short mash allows for malt backbone to come out without overpowering sweetness



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ASBC Hot Steep Malt Sensory Method

625 S Irish Rd | Chilton, WI 53014 | 920.849.7711 | www.Briess.com

Hot Steep

Application of method: sensory evaluation of extractable malt flavors and aromas

Target audience: sensory panels, brewers

Reagents

(a) Whole kernel malt
(b) Deionized water

Apparatus

(a) Thermos®, insulated, stainless steel, 24 ounce volume
(b) Thermometer, standard, 0-200°C
(c) Heating apparatus, capable of heating water to 65°C
(d) Funnel, plastic, short stem, 16 cm in diameter or similar
(e) Filter paper, fluted, 32 cm in diameter (Ahlstrom No. 515 or similar)
(f) Electric Grinder, 3 ounce volume, 200-watt (KRUPS F203 or similar)
(g) Glass Beaker, tall, 600 mL volume
(h) Graduated cylinder, 500 mL volume
(i) Analytical balance, capable of weighing 50.0 g (± 0.1 g)

Place approximately 52 grams of malt in electric grinder. Close lid and grind for 10 seconds, or until a course flour consistency is achieved (see Notes 1-2). Weigh 50 ± 0.1 g malt flour into Thermos®. Pour 400 mL of 65°C distilled water into Thermos®. Cap and vigorously shake contents of Thermos® for 20 seconds to ensure malt grist is completely wetted and mixed into solution. Let Thermos® sit for 15 minutes. During this time, place filter paper inside funnel and wet paper with deionized water to minimize aroma contribution. Position filter and funnel over mouth of 600 mL glass beaker where it will remain for wort collection. When 15 minute timer ends, vigorously swirl contents of Thermos® for 20 seconds to bring settled particles back into solution, then uncap and quickly pour all of the mash liquid into the filter (see Note 3). Collect and pour first 100 mL of filtrate back into the Thermos®. Swirl Thermos® to collect any grist that remains inside, then gently re-pour back into the filter. Allow wort to filter to completion (see Notes 4-6).

Notes

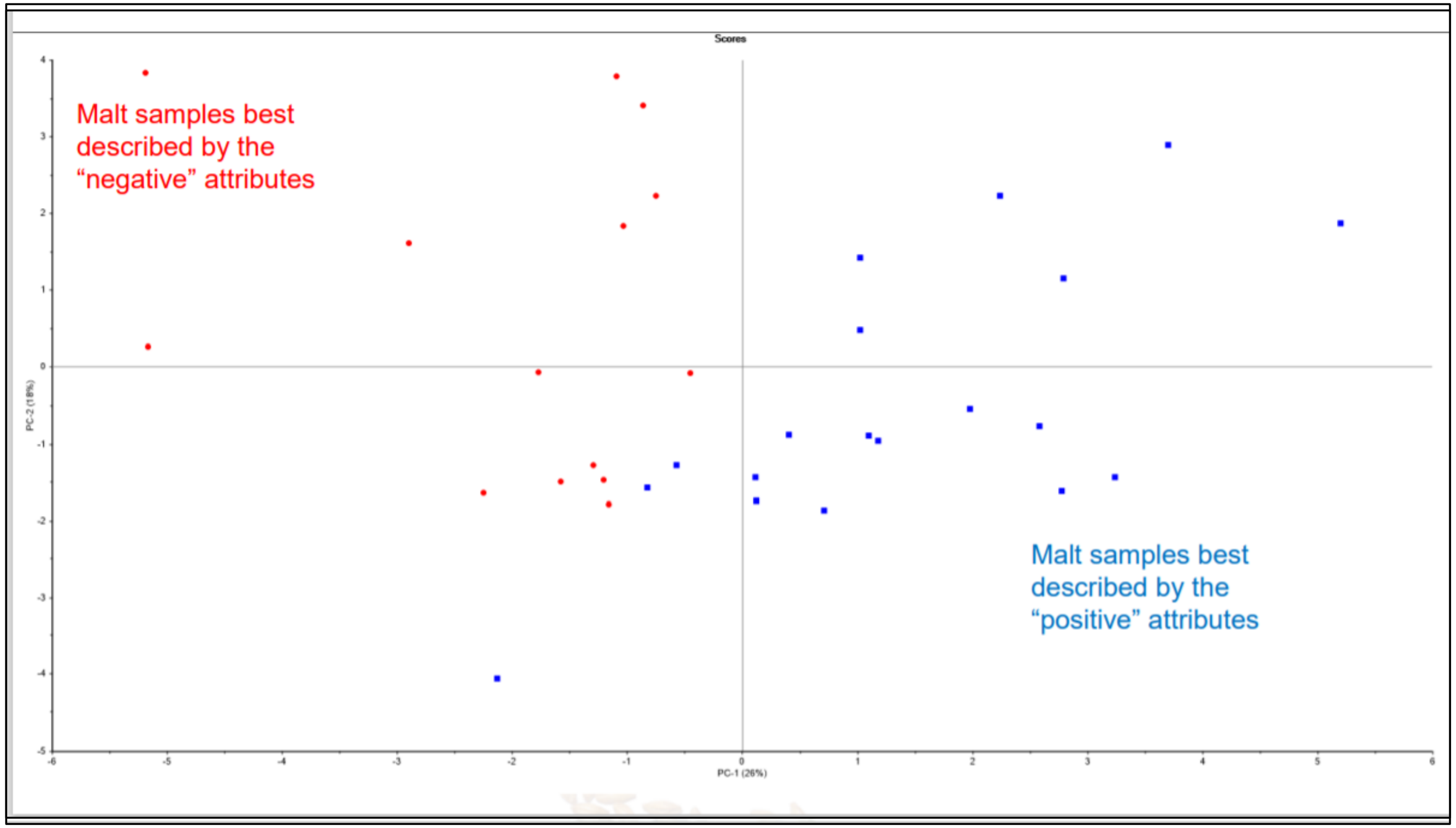
1. Evaluate base malts with 50 g of sample (100% inclusion), specialty malts with 25 g of sample and 25 g of brewers base malt (50% inclusion), and dark roasted specialty malts with 7.5 g of sample and 42.5 g of brewers base malt (15% inclusion).
2. If different malts are to be milled, clean electric grinder with a dry rag in between samples to prevent cross contamination.
3. Entire contents must be poured though filter at once so that the grain bed can settle without being disturbed. Filter paper should be free of aromas and large enough to hold the entire contents of the Thermos®.
4. Filtration rate and sample yield will be influenced by malt type and modification level. Approximately 300 mL of wort can be collected in 30-45 minutes (serves 6-8 tasters).
5. In the event that a large batch of wort is needed to accommodate more than 6-8 tasters, the method can be scaled up by a factor of x, with x being equal to the amount of Thermos® containers, filter papers, funnels, and glass beakers that are required. Blend the wort collected to obtain a homogenous sample.
6. Perform wort sensory evaluation within four hours of filtration. Serve at room temperature.

The best handcrafted beer starts with the finest handcrafted malt.

New Belgium – Does Variety Matter?

- Questions:
  - Can the hot steep method produce data to help inform brewery decisions?
  - Are there distinguishable varietal flavor differences?
- Trained panelists scored flavor according to intensity

PCA Bi-Plots:
- 2 dimensional figures representing variation in samples
- Points that are close to one another are similar, those that are far apart are less similar/more different



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Does Base Malt Flavor Matter – Is there a Difference?

Four malts selected:

- A/B: Two varieties, different crop years, grown in the same region, malted at the same malthouse and using the same malt regime
- C/D: Two varieties from different growing regions, malted at different malthouses and with different malt regimes
- Blind, paired comparison test. Panelists asked to indicate preference

Malt sensory

- Same growing region, malthouse, recipe
- Difference is not significant at α = 0.05

- Different growing region, malthouse, recipe
- Difference is significant at α = 0.05

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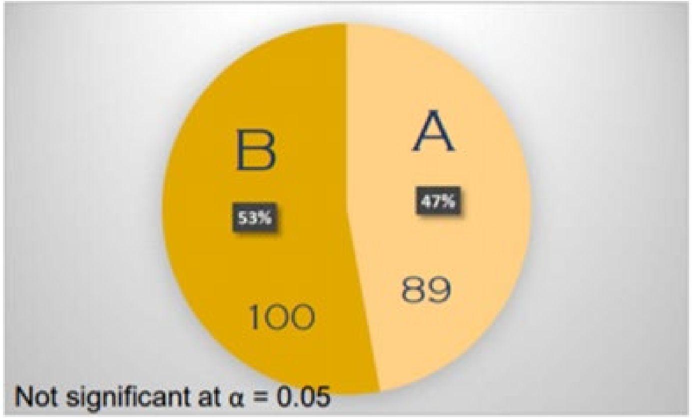
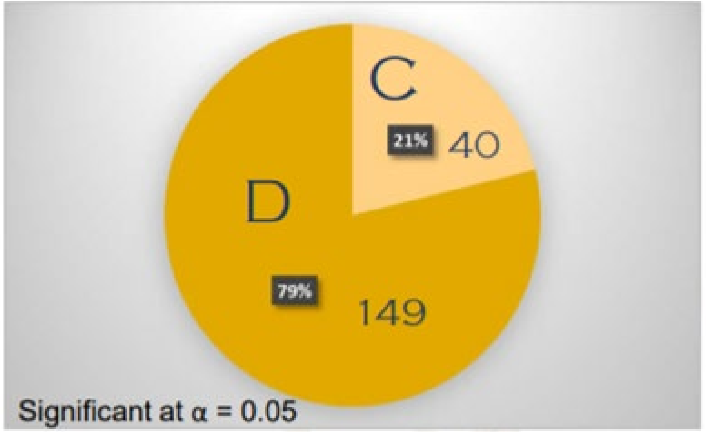
Does it Translate to the Beer?





- Malts brewed (Helles beer) on Briess Pilot Brewery. All brewed the same day, same hops, same yeast – malt was the only variant.
- Results from a larger groups
  - National Homebrew Conference
  - ~200 panelists
  - Samples distributed in balanced random pattern
  - Preferences recorded live

Same *preferences* found among groups tasting beers as in tasting malts

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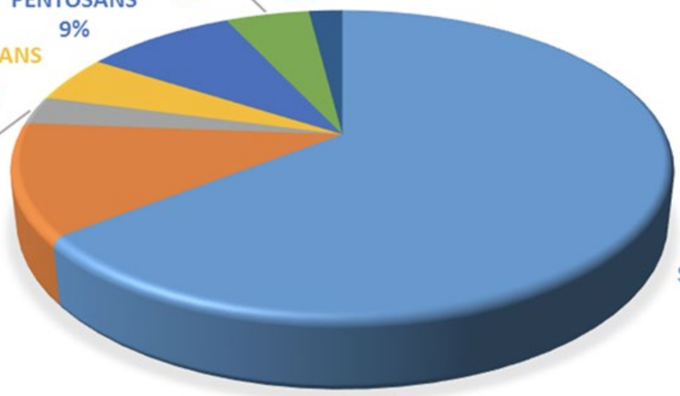
Impacts on Malt Quality & Sensory Aspects

- Genetic makeup
  → Inherited development and response controls
- Environmental variation
  → inputs to the system
  →Includes separately, growing and malting

G x E

Chemical Composition Of Malt

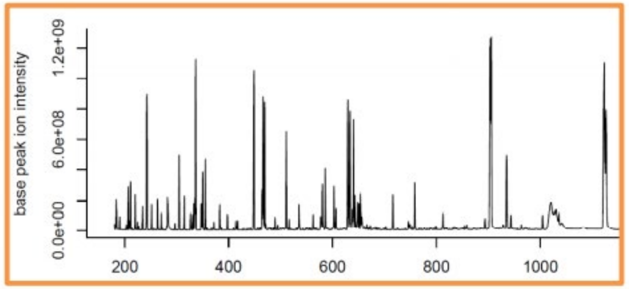
Barley Composition

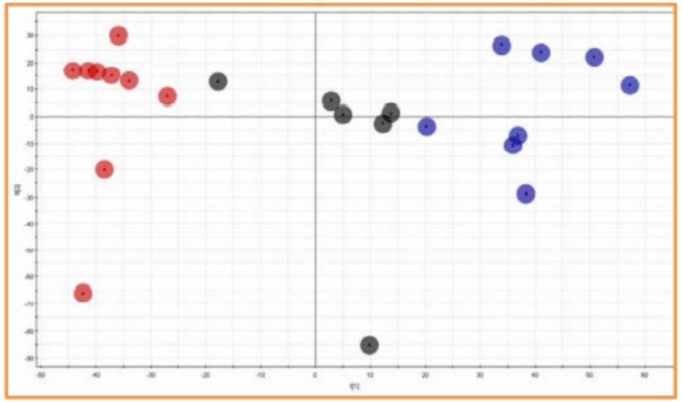


- Starch: 60-65%
  - extract, contributes carbohydrates and sugars to kiln browning
- Protein: ~10-13.5%
  - enzymes, flavor, head retention, processing
- B-glucans: 3-5%
  - sugars, if properly modified → extract
  - Improperly modified will potentially add viscosity and processing issues
- Arabinoxylans (pentosans)
  - another cell wall component – high levels in wheat and rye
- Lipids & Polyphenols
  - small amount – can contribute to staling, astringency
- Minerals: 2-3%
  - perhaps have a roll in Terroir?

Malt Chemical Analysis – Mass Spectroscopy

Liquid Chromatography (LC-MS)   Gas Chromatography (GC-MS)

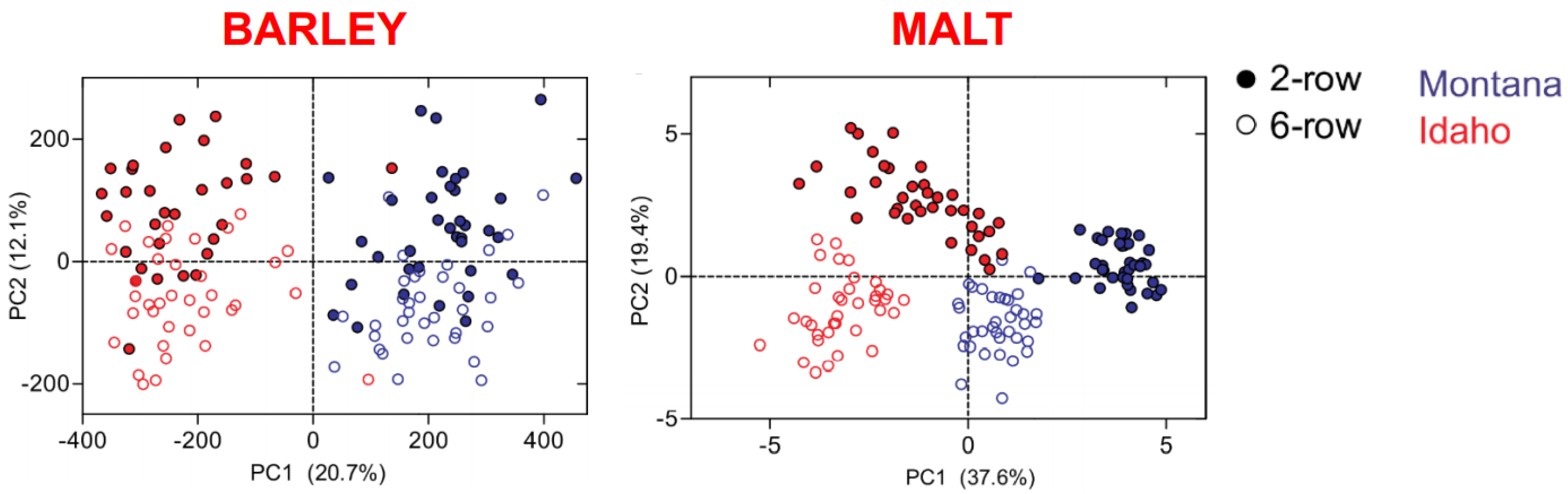




Highly sensitive analytical means for detecting compounds

Malt Metabolites Influenced by G & E

Malting exacerbated genetic differences in both 2 and 6 row varieties grown in MT and ID



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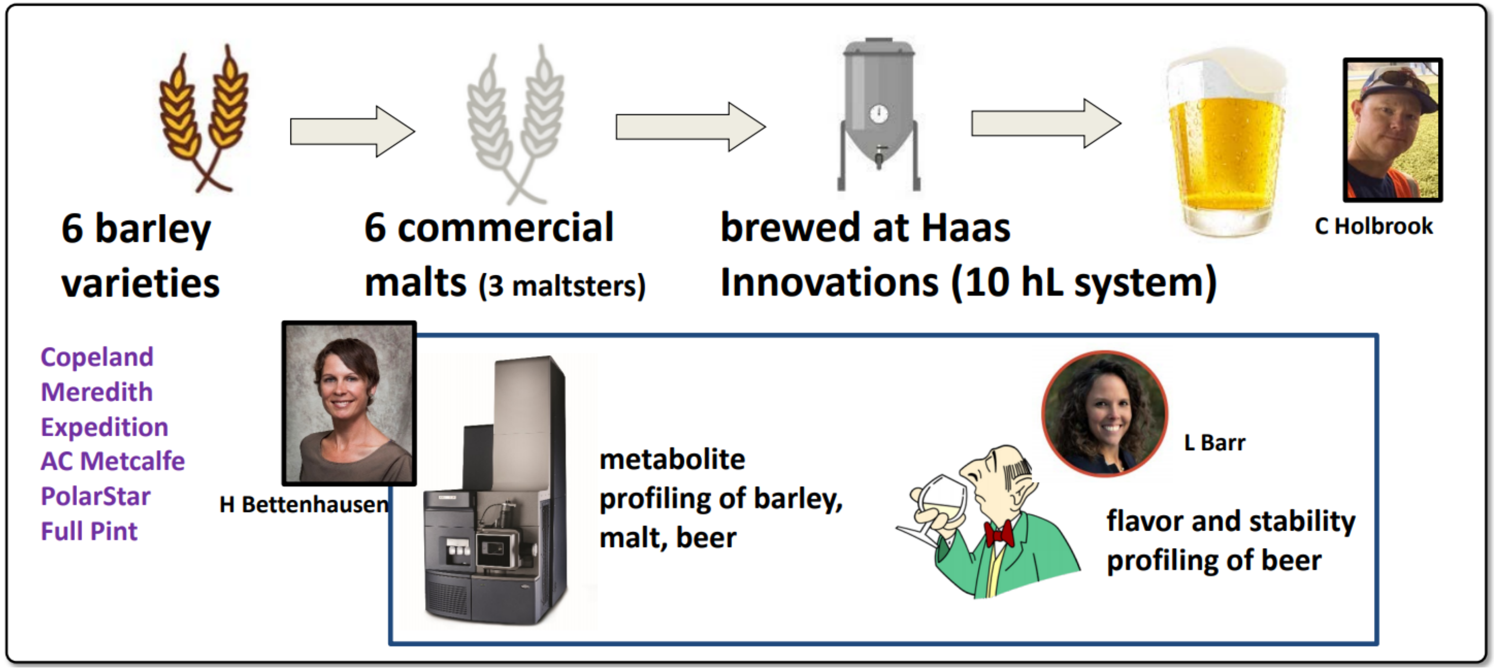
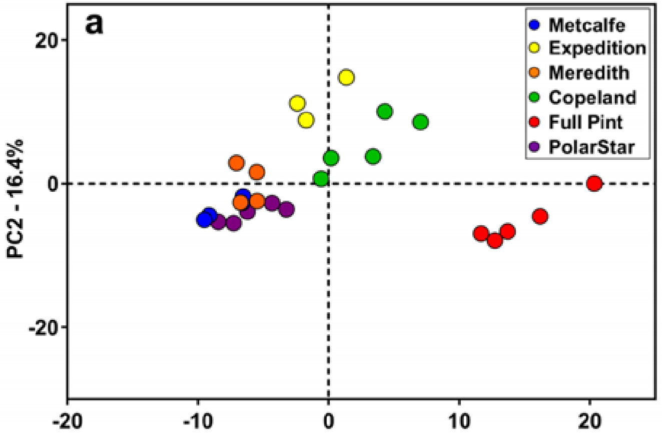
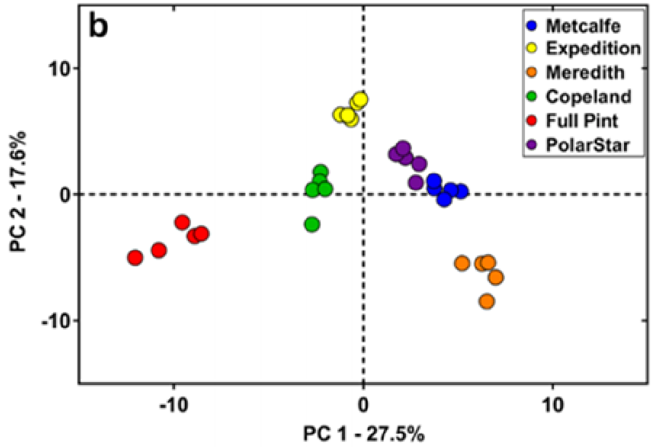
Malt Chemical Variation Influence on Beer



Malt Metabolite Profiles Differed



Beer Metabolite Profiles Differed



Distinct metabolite profiles were found for both malt and beer

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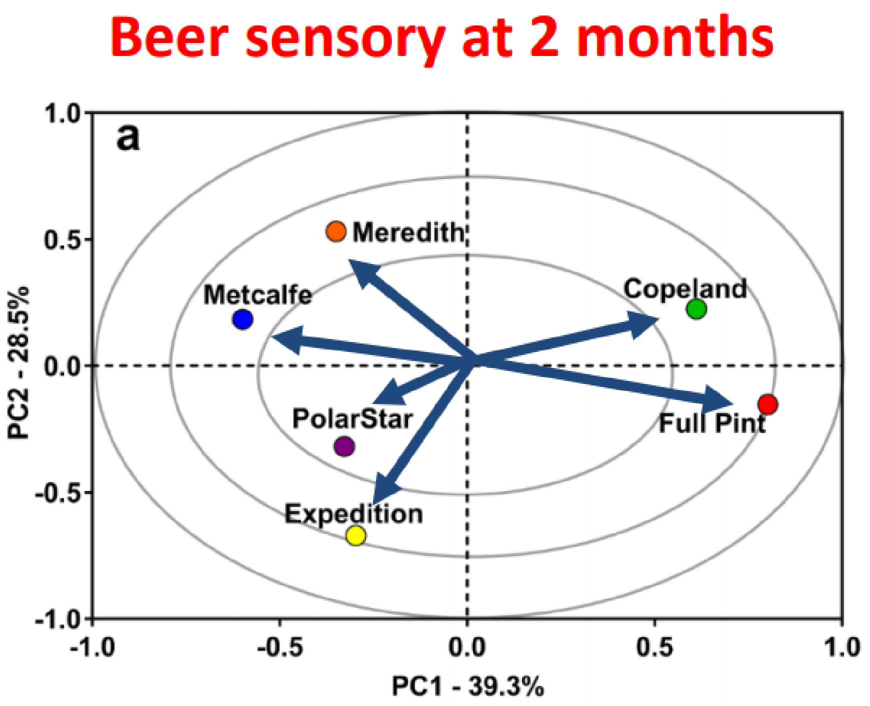
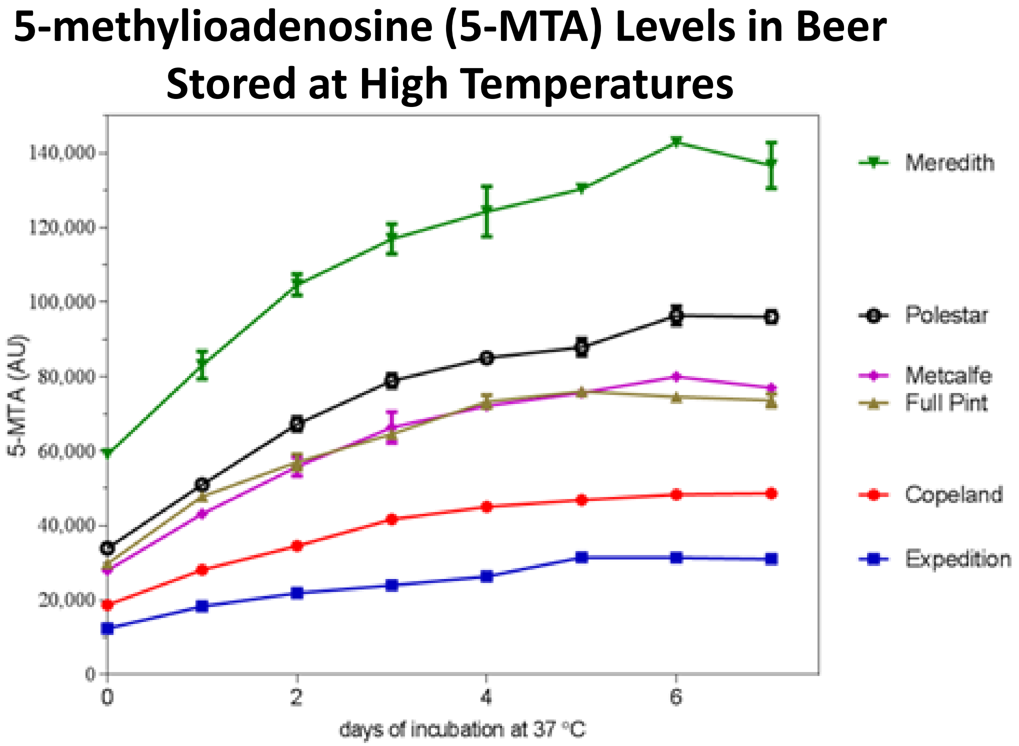
Sensory Evaluations and Flavor Stability





- 5-MTA is a measurable marker which correlates sensory profiling and analytical measures
- Flavor stability dynamics: Measures 5-MTA abundances at high temperatures over a 6-day time period.
- Data indicates Expedition is more flavor stable than Meredith.

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Why is it that brewers feel heirloom varieties have better flavor?

- Barley breeding -- historical perspectives
  - North American barley breeding began to focus on malt quality after WWII
  - Industry dictated breeding goals – adjunct brewing
    - Yield, disease resistance, enzymes, FAN etc.
  - Flavor not considered in breeding for the past 70 years
- Has varietal flavor been lost?
  - Often variety is not reported with malt
  - Malts are named by the kiln process not by the variety
  - Brewers lust for Maris Otter and Golden Promise
    - rare malts known for the variety

Varietal flavor differences in wort and beer

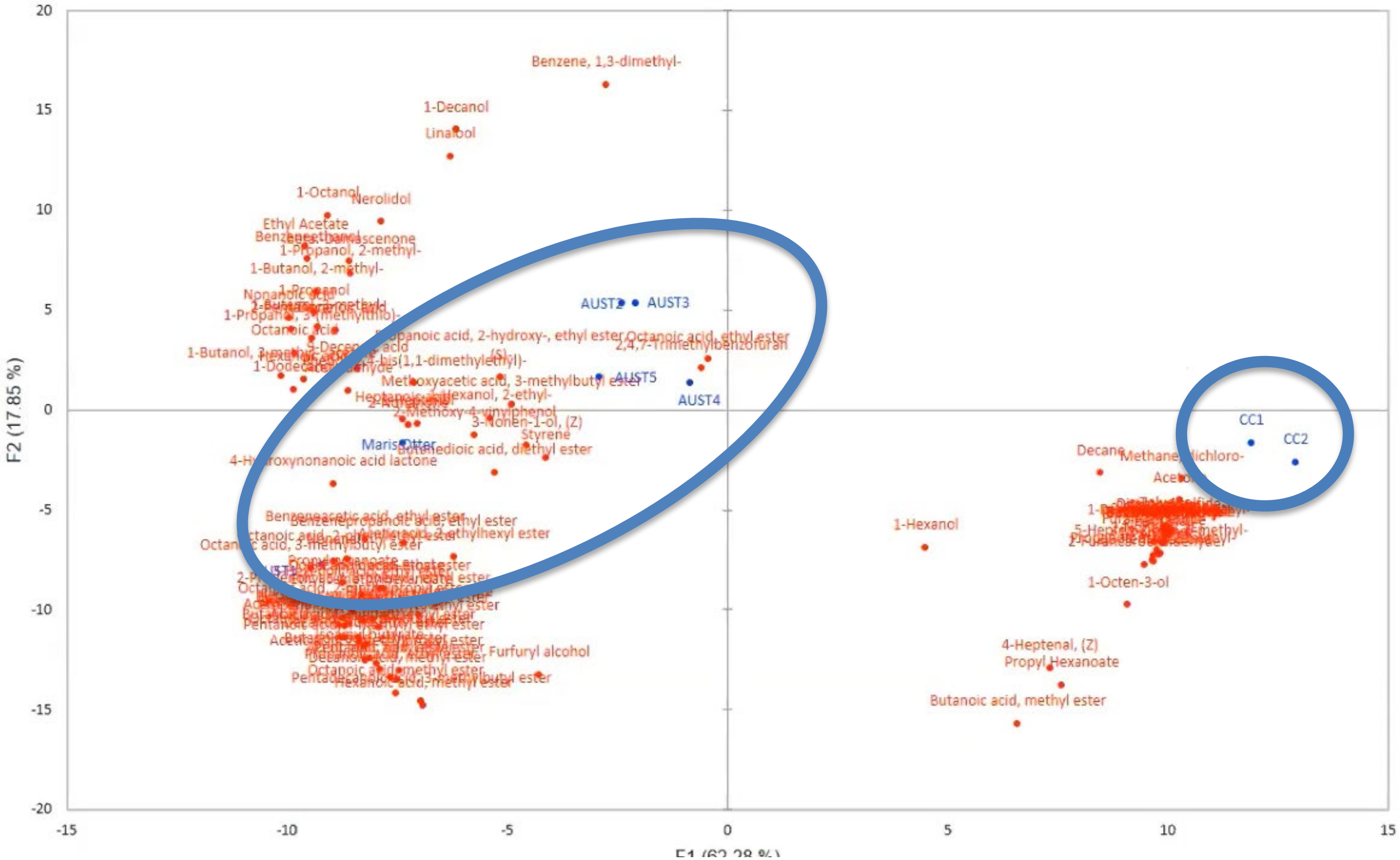
-Recent Australian Study-

Canadian varieties found to have less flavor compounds than Australian varieties

- 5 Australian varieties, 2 Canadian and Maris Otter (UK heritage)
  - Canadian varieties had higher and more unique aldehydes
  - Australian varieties had higher and more unique esters and alcohols

WBC 2021, Flavor differences in wort and beer brewed from different barley varieties, Sue Stewart – University of Adelaide

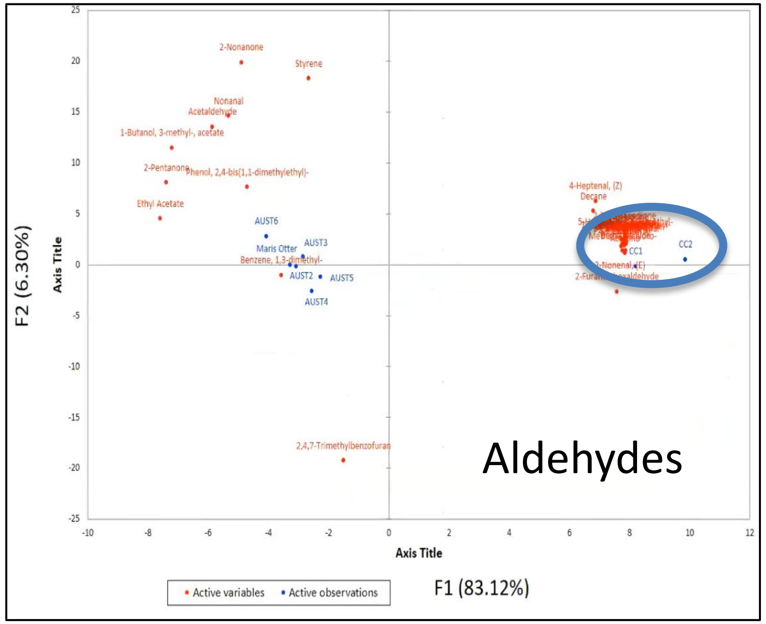
Summary of 106 Compounds Measured

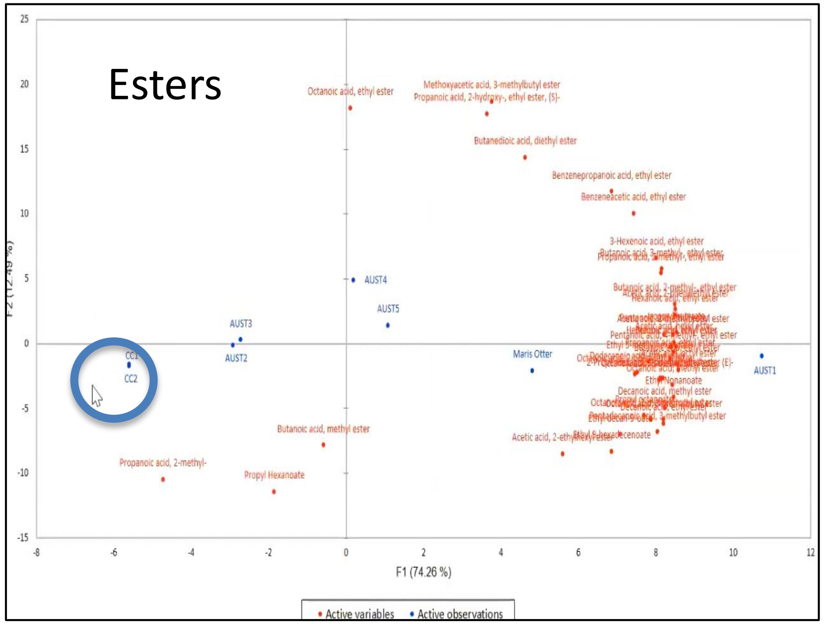


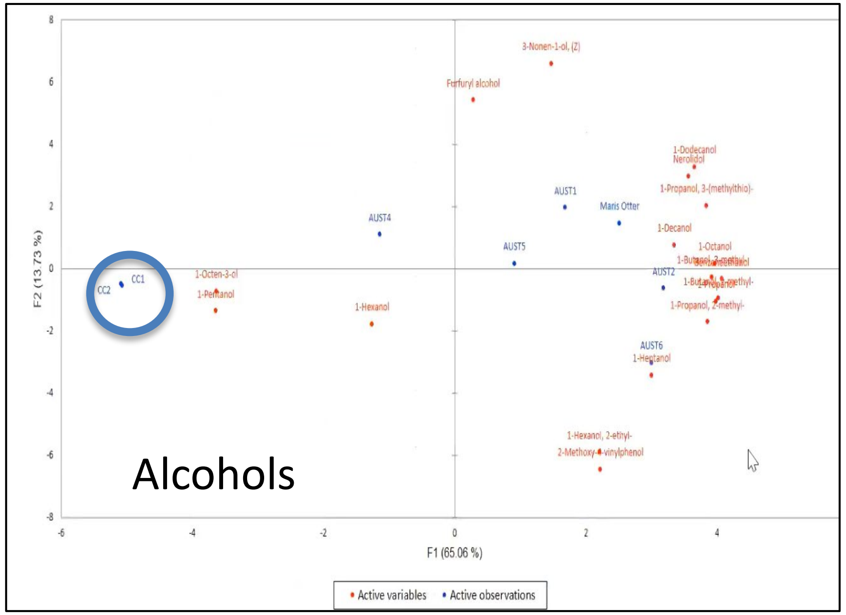
- Compounds are in red
- Varieties are in blue
- Compounds nearest each variety are most responsible for differences between variety

WBC 2021, Flavor differences in wort and beer brewed from different barley varieties, Sue Stewart – University of Adelaide

Chemical Differences







Compounds low → high in each figure

WBC 2021, Flavor differences in wort and beer brewed from different barley varieties, Sue Stewart – University of Adelaide

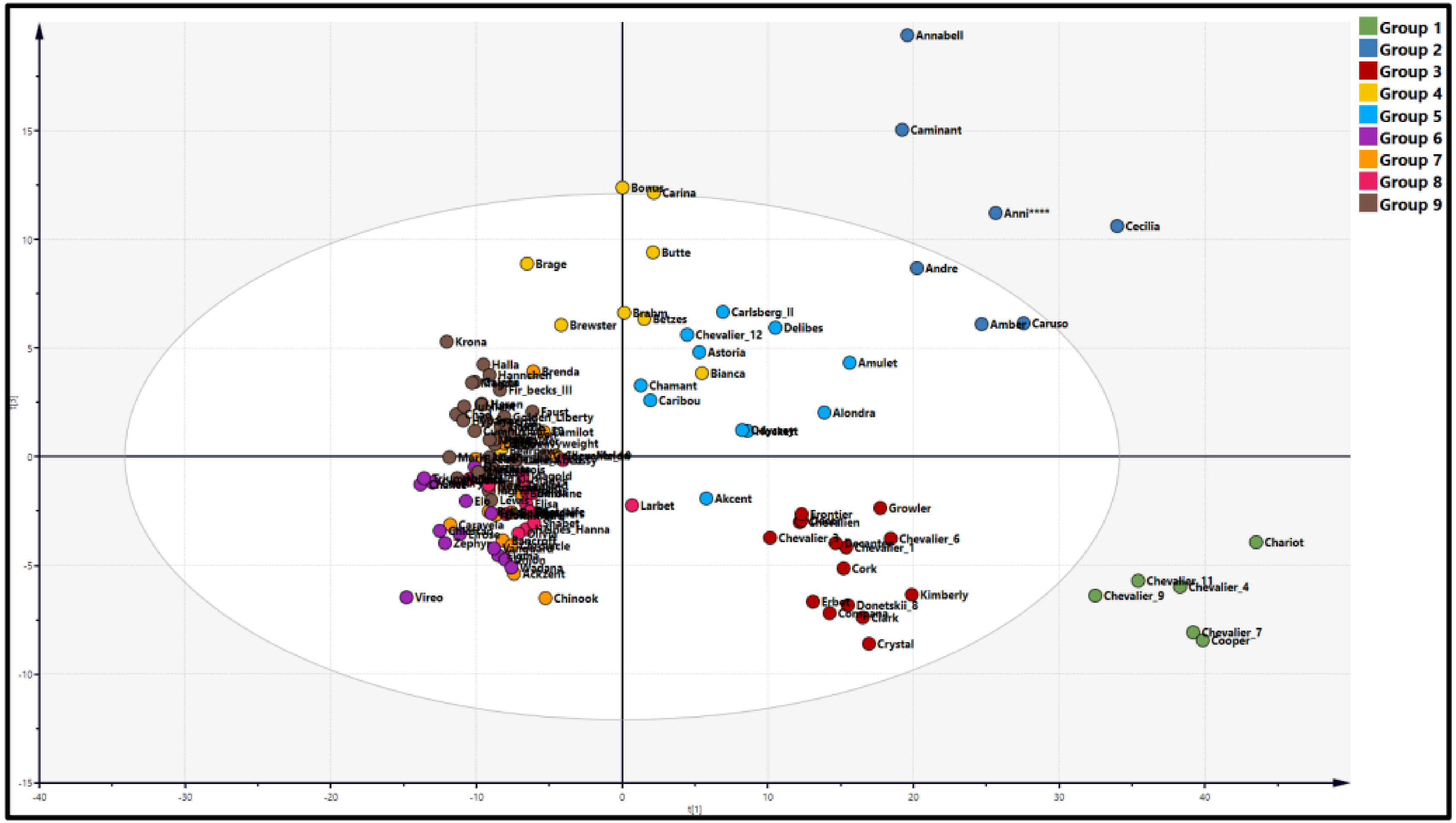
MSU-CSU Heirloom Flavor Research

- 300 Heirloom varieties collected from seed banks and germplasm around the world
- 42 Countries represented
- Joint USDA study
  - Montana State University:
    - growing, malting, brewing, genetic dissection
  - Colorado State University:
    - Chemical profiling and sensory analysis

MSU-CSU Heirloom Flavor Research

Chemical profiles of heirloom malts:

9 unique groups characterized



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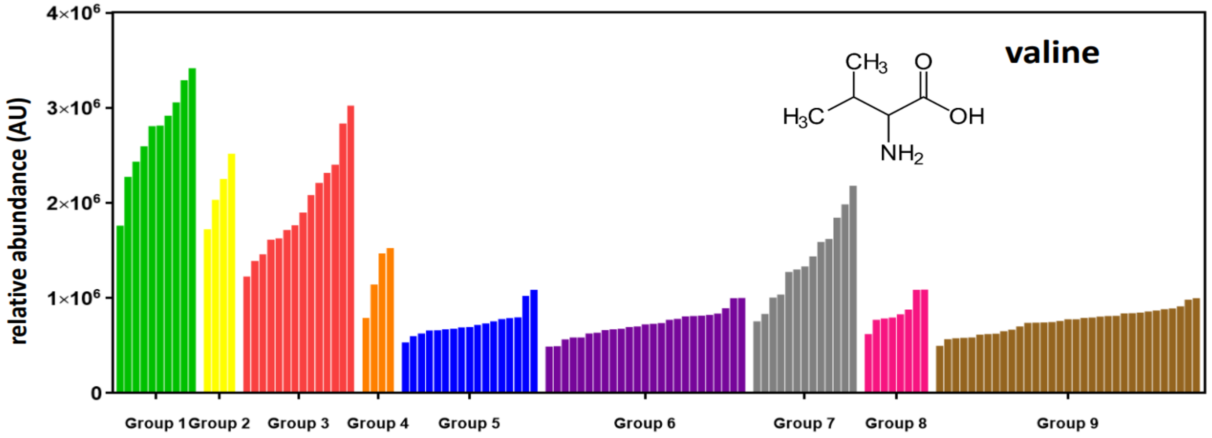
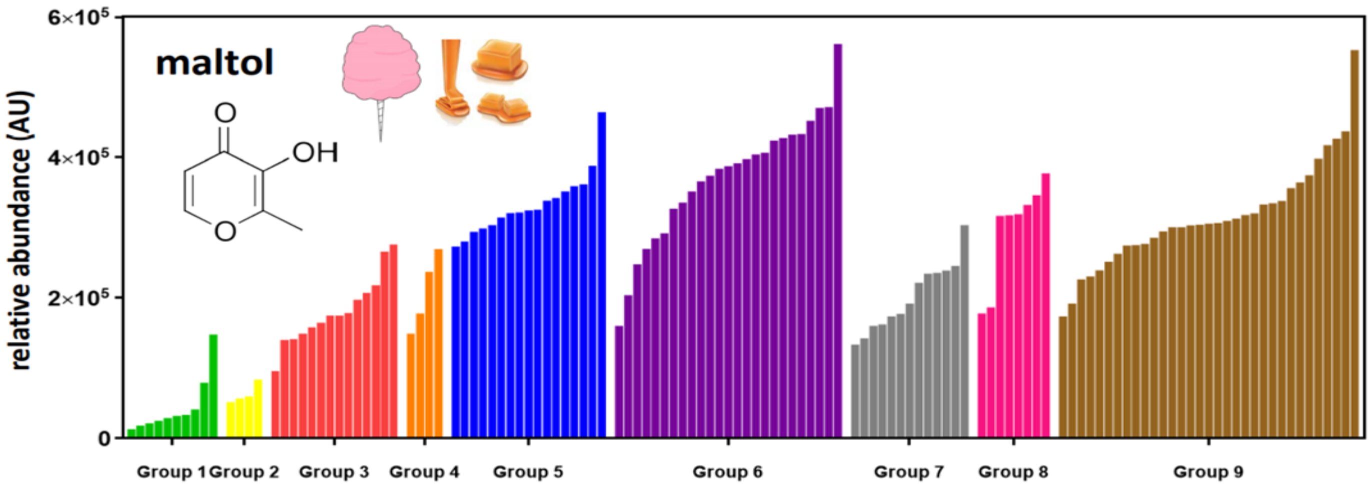
Variations Within and Between Groups



Amino Acids

Flavor Compounds



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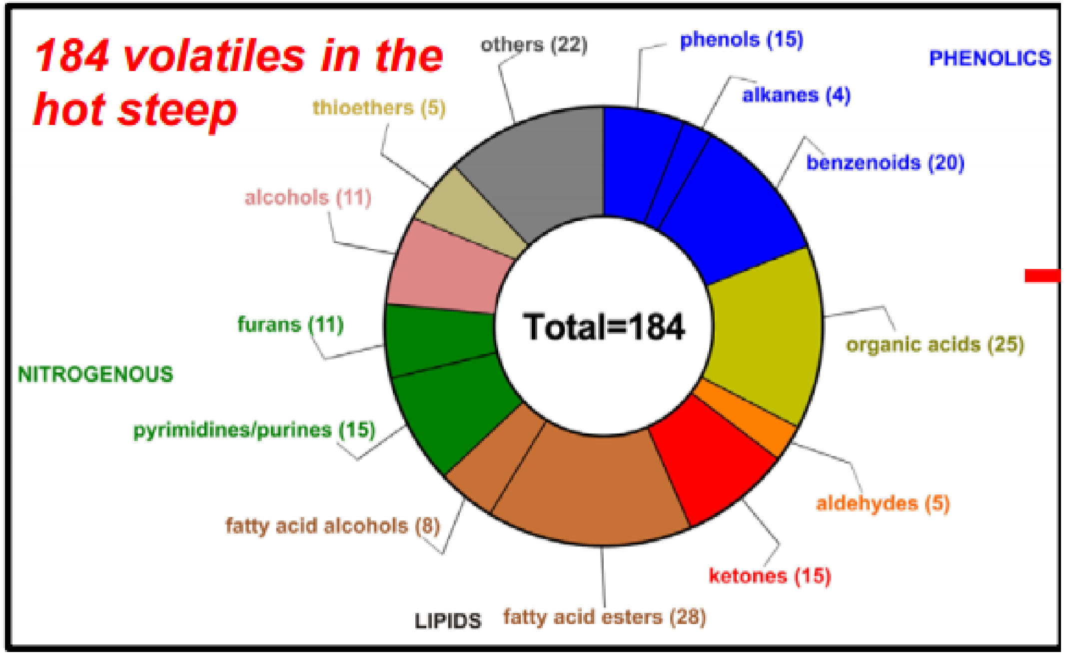
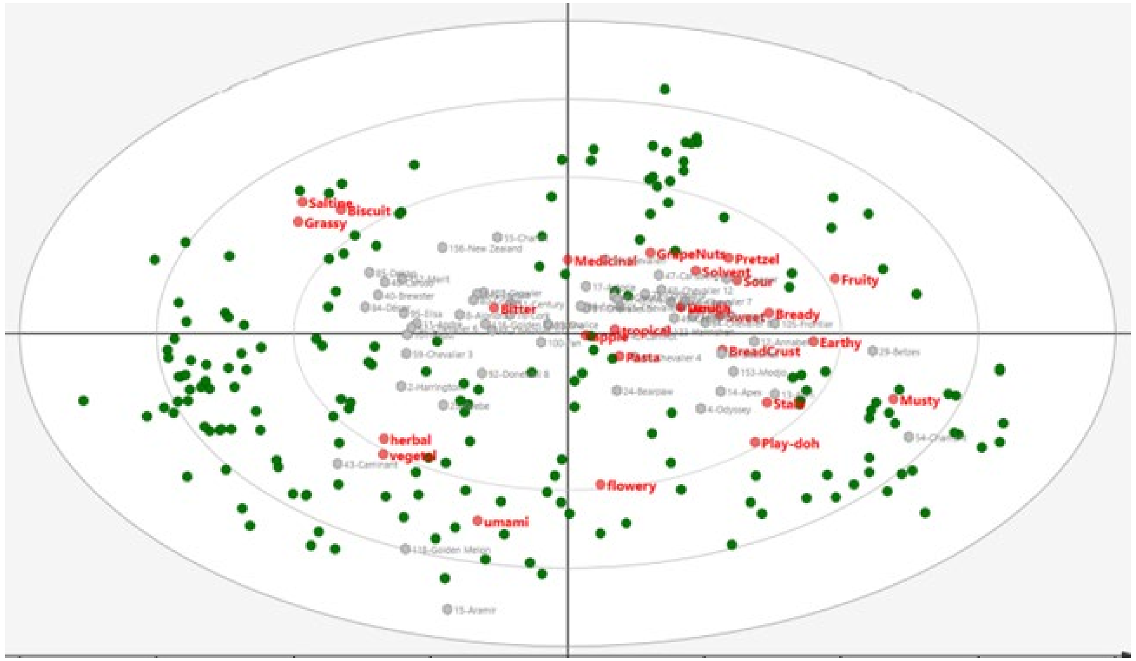
Aroma Variations

Headspace analysis – characterization of volatile compounds





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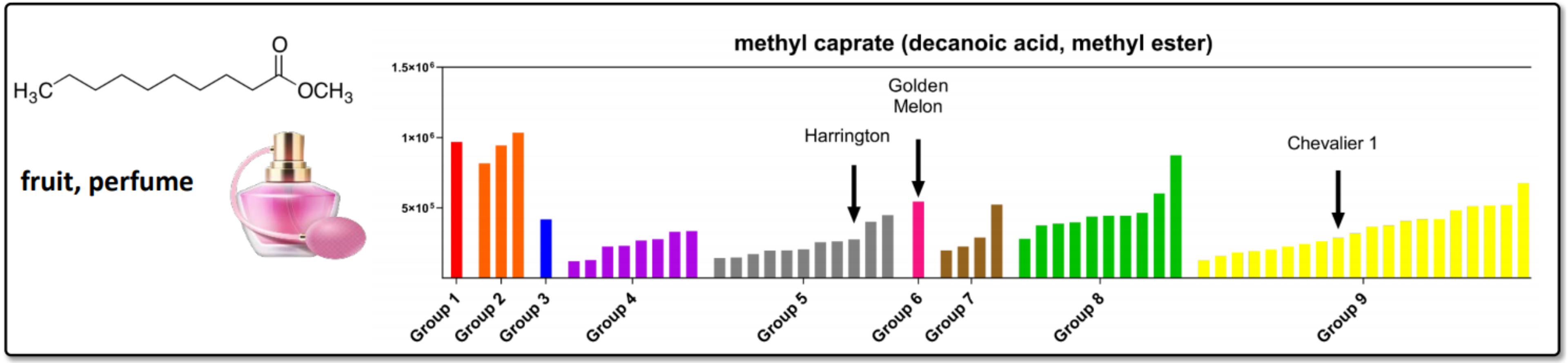
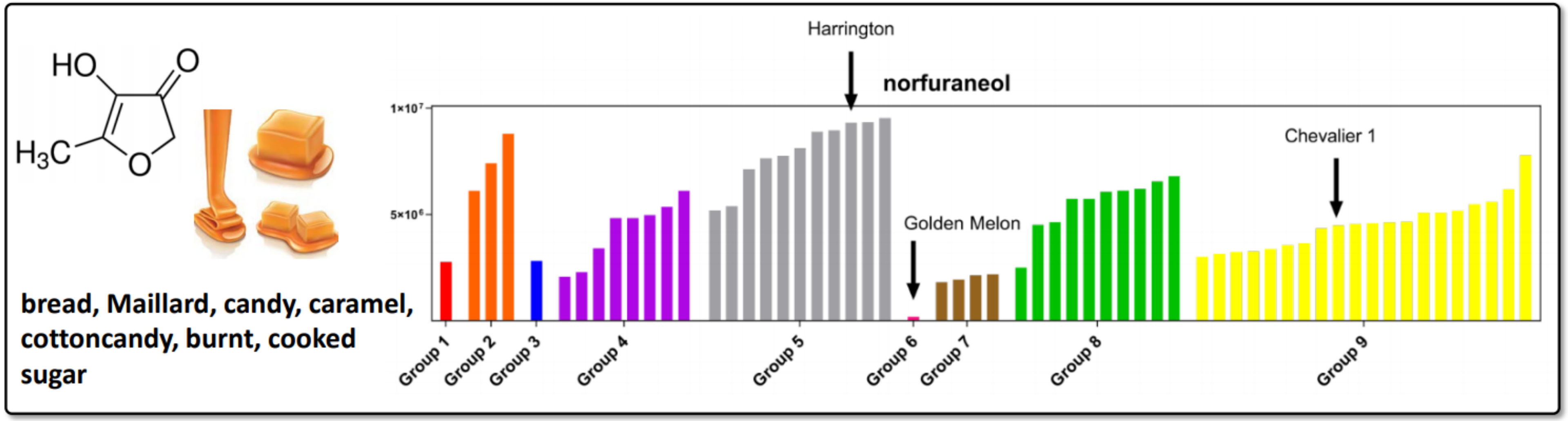
Making Varietal Comparisons





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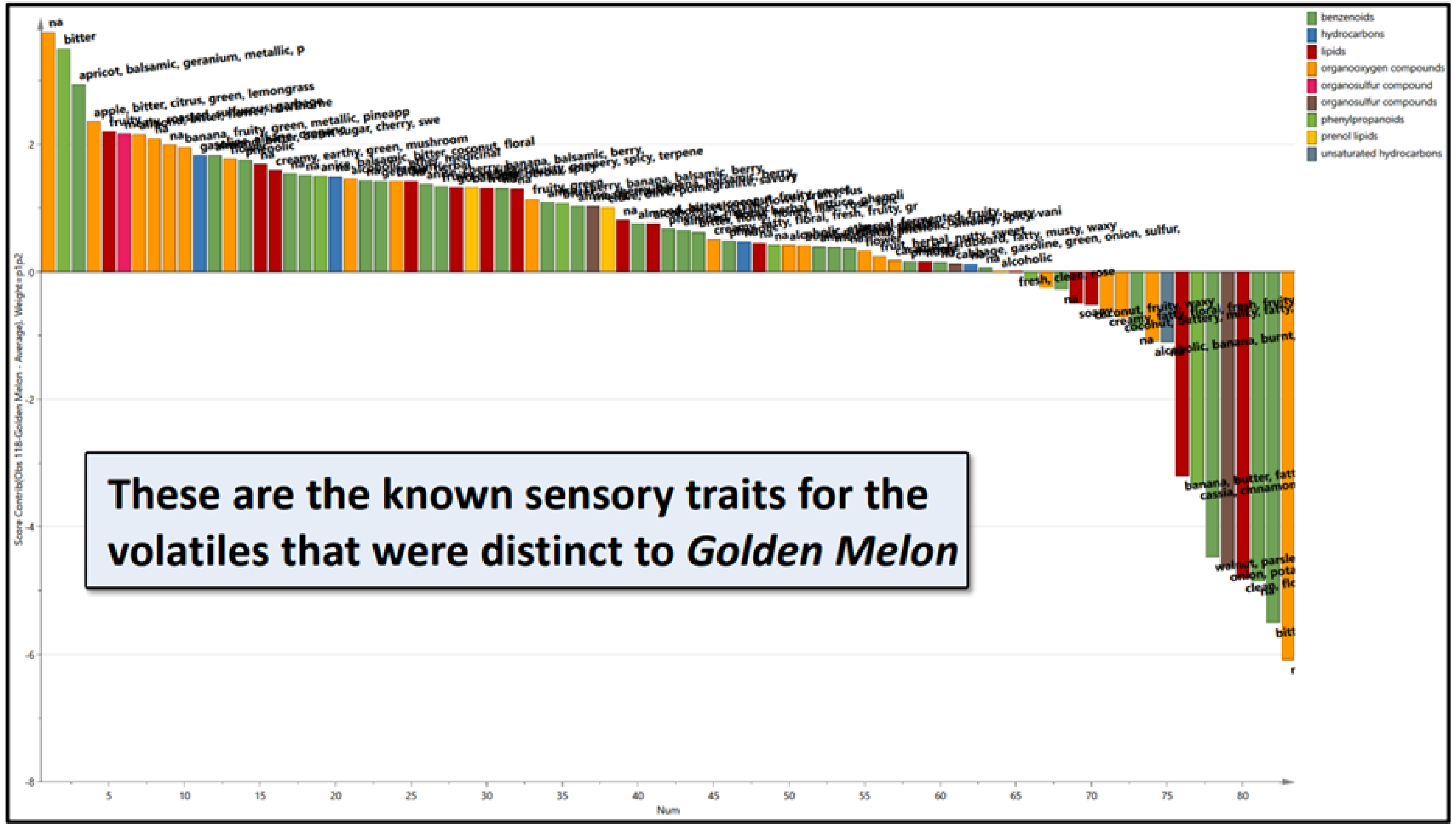
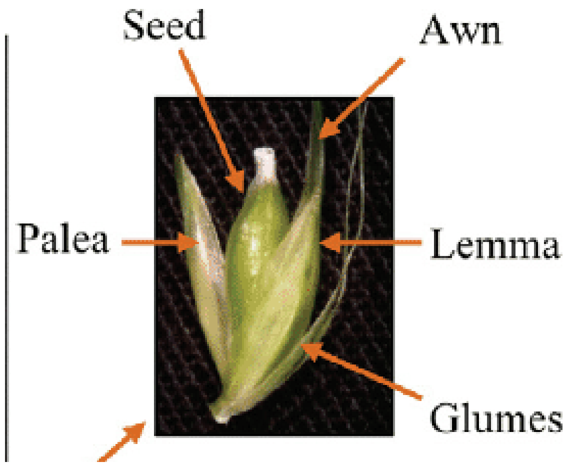
Golden Melon – Japanese Heirloom

Contribution Plot – shows how different each metabolite is in Golden Melon compared to all other heirlooms





Fun fact: Golden Melon has a unique physical characteristic, it has a yellow lemma!

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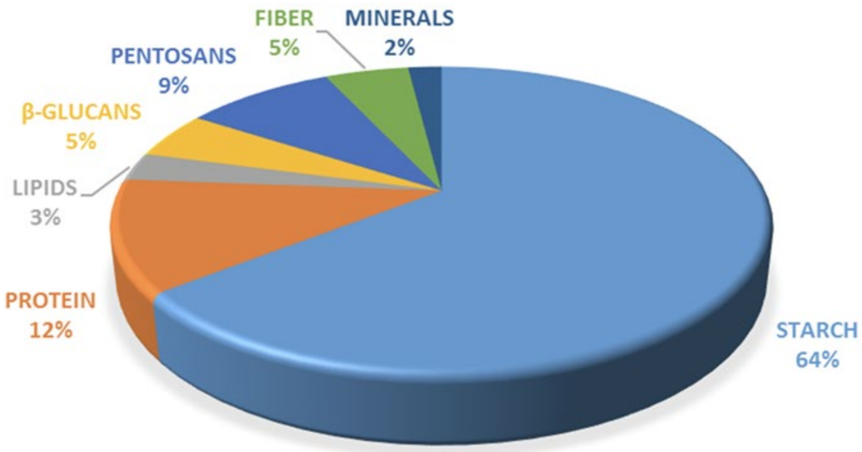
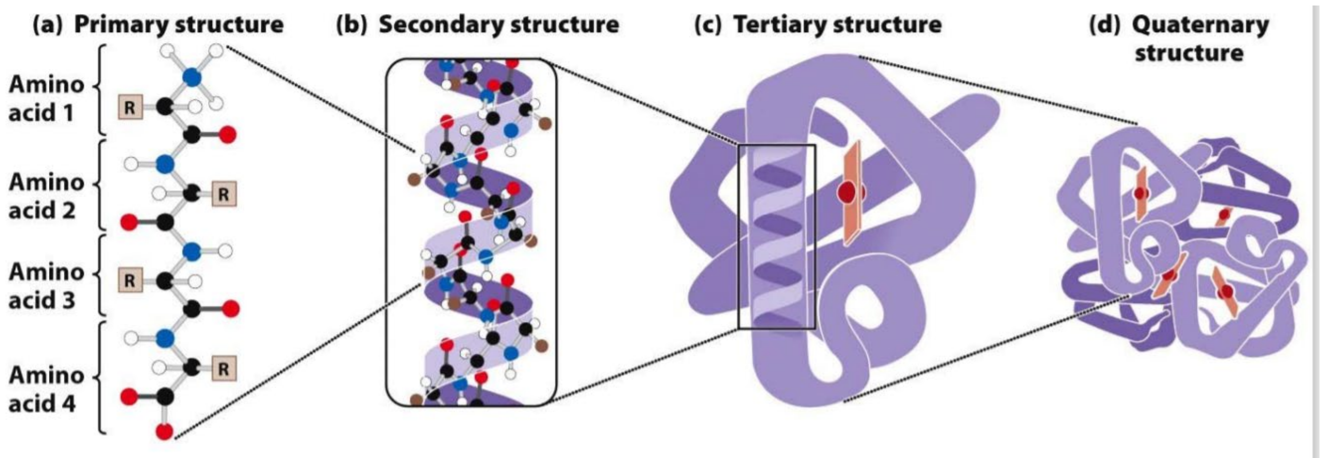
Barley Composition

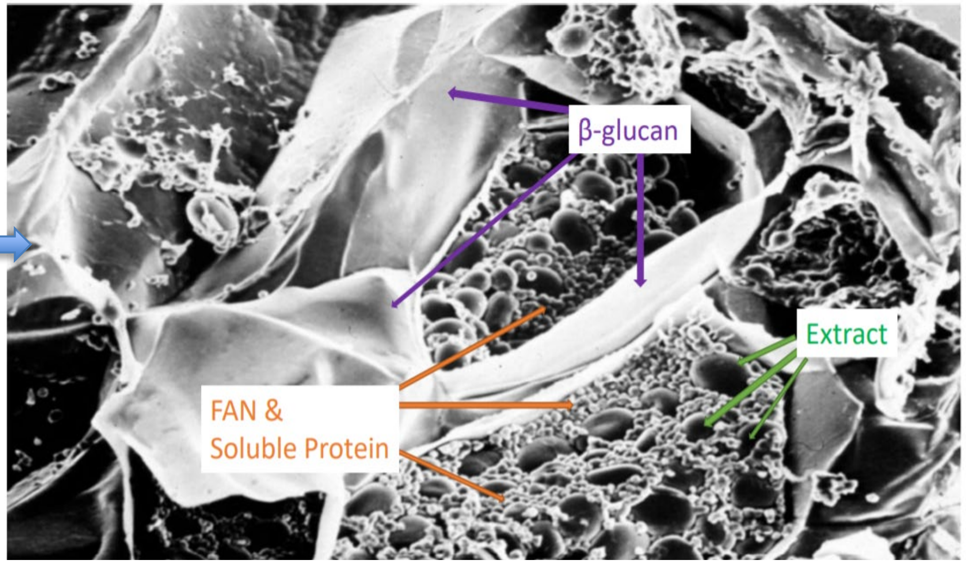


- Starch: 60-65%
  - extract, contributes carbohydrates and sugars to kiln browning
- Protein: ~10-13.5%
  - enzymes, flavor, head retention, processing
- B-glucans: 3-5%
  - sugars, if properly modified → extract
  - Improperly modified will potentially add viscosity and processing issues
- Arabinoxylans (pentosans)
  - another cell wall component – high levels in wheat and rye
- Lipids & Polyphenols
  - small amount – can contribute to staling, astringency
- Minerals: 2-3%
  - perhaps have a roll in Terroir?

Protein Structure



Composition of barley endosperm



Like an old school telephone chord

- Individual amino acids form the chord
- The chord is wound in a secondary (helical) structure
- The chord tangles and creates tertiary structure → proteins
- Proteins can fit together like 3D puzzle pieces to function in lots of different ways (Quaternary structure)

Barley Protein Types

- Glutelin:
  - ~30% of barley protein, insoluble in water, passes unchanged to spent grains
- Albumin and Globulin
  - ~25% of barley protein – largely enzymatic portion of protein
  - Contribute to beer haze and foam stability
- **Prolamin, aka hordein in barley**
  - ~37% of barley protein - reduced by more than half in malting
  - Forms a matrix around starch
    - Degradation directly impacts starch availability for brewing

Varieties vary in composition, proteins vary in amino acid composition

FAN – Free Amino Nitrogen = Amino Acids

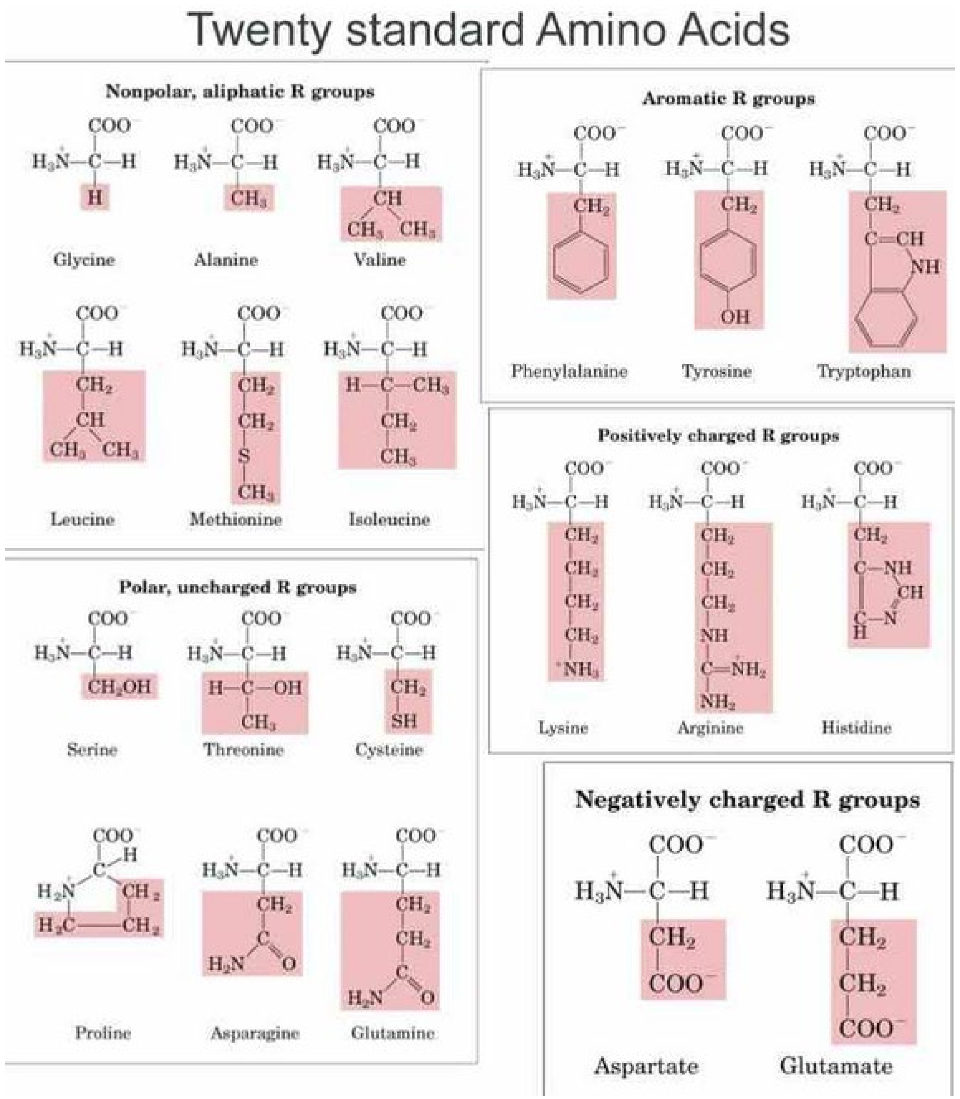
Partially Partially

Hordein protein → Soluble Protein → Individual amino acids (FAN)

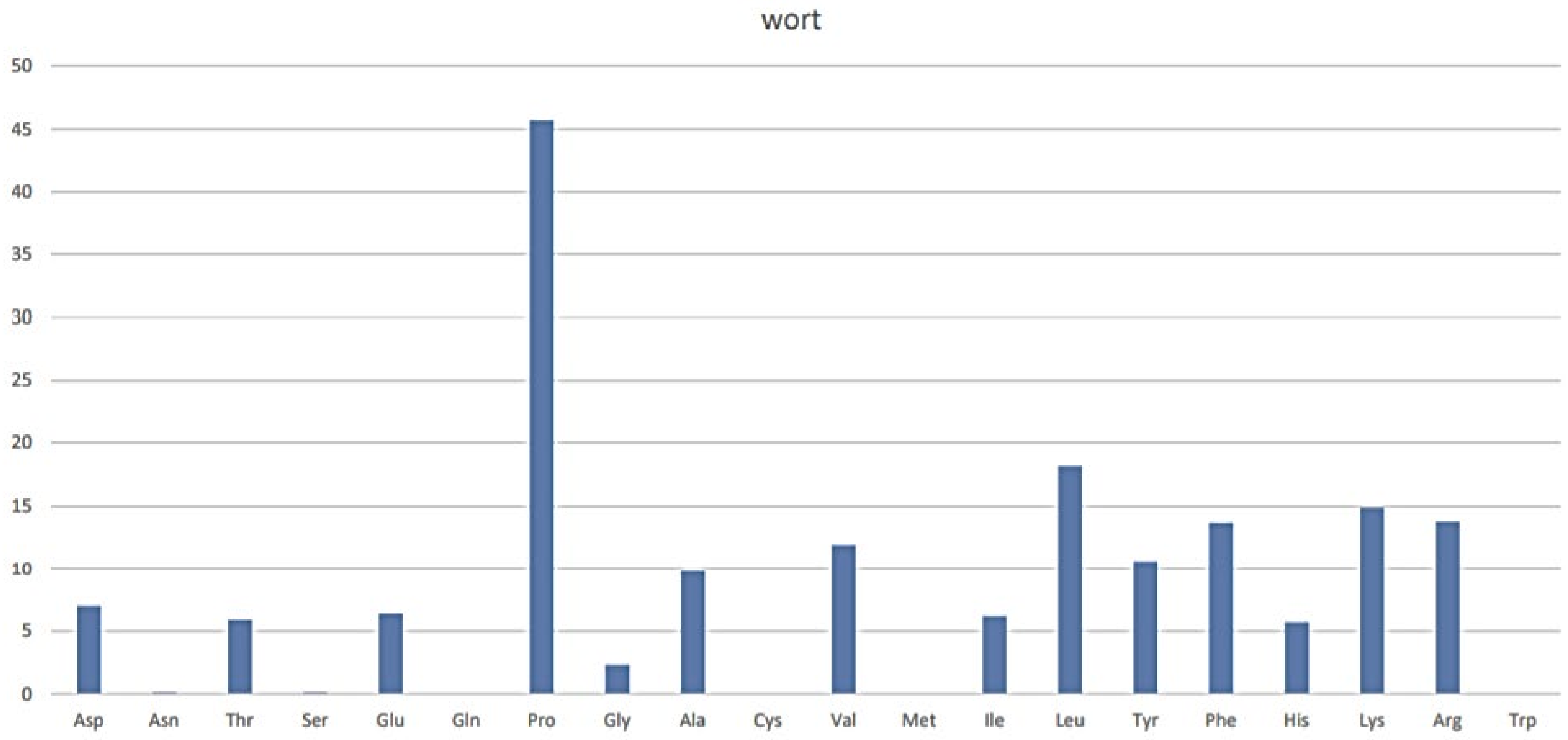
- Grain protein
  - Pre-cursor material for FAN → Impacted by environment, variety, agronomic
- FAN, a.k.a. = "assimilable nitrogen"
  - Important nutrients for yeast health
  - low FAN levels can cause issues with fermentation, High FAN can lead to over expressive yeast
- FAN remaining in beer is food for flavor negatives
  - Issue if you are packaging or aging, faster aging and lower flavor stability

Amino Acids

- 20 naturally occurring amino acids
- COA doesn't provide information about the amino acid composition, just total (FAN)
- Reporting individual amino acids is impractical – the testing is lengthy and expensive



Amino Acid Composition of Wort – an example



Ferreira and Guido. 2018. Fermentation 4:23

Yeast absorb amino acids with varying efficiency

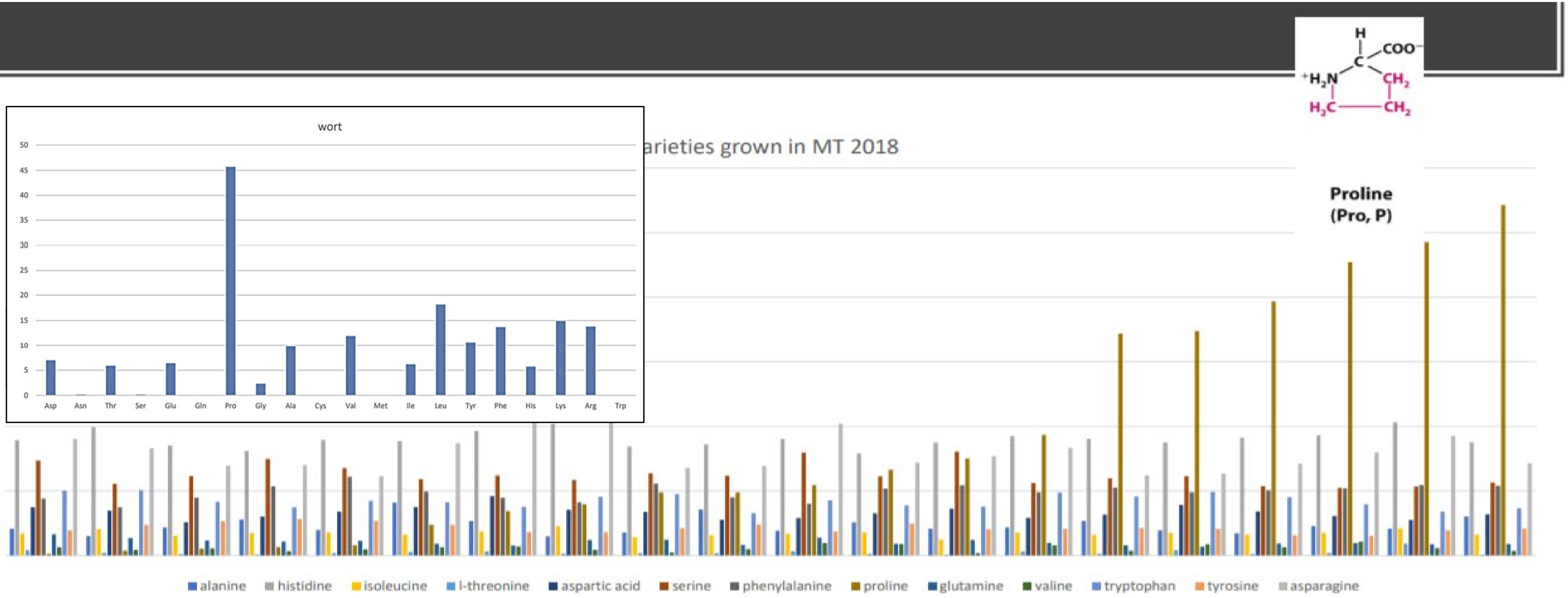
Proline remains in wort to beer

Will varieties with varying proline have varying impact on beer flavor and staling?

Classification of Amino Acids By Speed of Absorption From Wort Under Brewery Conditions			
Group	Amino Acid		Description
A	Glutamic acid Aspartic acid Asparagine Glutamine	Serine Threonine Lysine Arginine	almost totally removed from wort after 20hrs
B	Valine Methionine Leucine	Isoleucine Histidine	absorbed gradually during fermentation
C	Glycine Phenylalanine Tyrosine	Tryptophan Alanine Ammonia	uptake coincides with end of A uptake
D	Proline		about 1/3 total amino N, essentially no uptake

Jones and Pierce, 1964

MSU Research in Progress: Amino Acid Variation in Heirloom Varieties



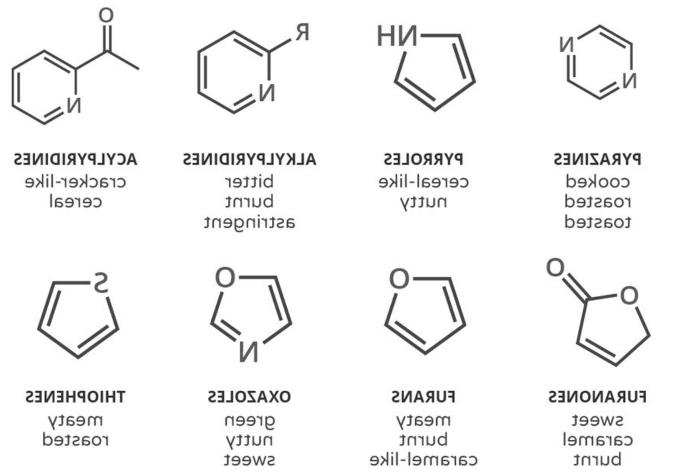
Proline – large variation in just these 20 lines (ranked low to high L-R)

How Barley Amino Acids Impact Flavor

Maillard Products

Almost all amino acids participate

Maillard products will change based on what amino acids and sugars are available



Strecker Degradation

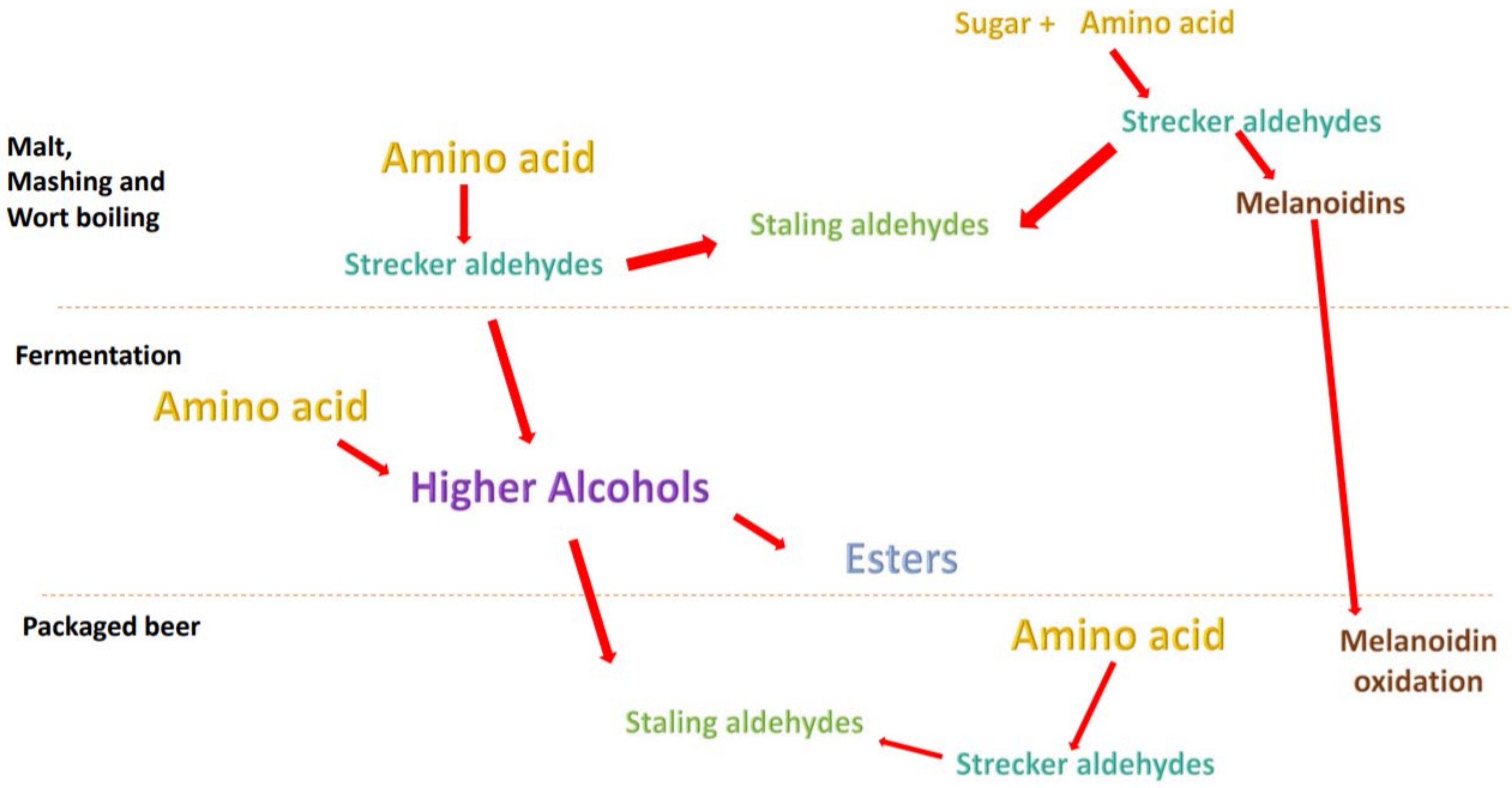
Direct and indirect interactions of amino acids to form Strecker products

Compound	Aroma Impression
2-methylpropanal	Grainy, varnish, fruity
2-methylbutanal	Almond, apple-like, malty
3-methylbutanal	Malty, chocolate, cherry, almond
Methional	Cooke potatoes, worty
Phenylacetaldehyd e	Hyacinth, flowery, roses
Benzaldehyde	Almond, cherry, stone

Ester and Higher Alcohol Formation

Compound	Aroma Impression
Ethyl acetate	Fruity, solvent-like
Isoamyl acetate	Banana, pear
Phenylethyl acetate	Roses, honey, sweet
Ethyl hexanoate	Apple, fruity
Ethyl caproate	Apple, aniseed
Ethyl caprylate	Apple
Ethyl octanoate	Apple, aniseed
Propanol	Alcohol, solvent-like
Isobutanol	Alcohol, solvent-like
Isoamyl alcohol	Alcohol, banana, vinous
Amyl alcohol	Alcohol, solvent-like
2-Phenylethanol	Roses, sweet
Tyrosol	Bitter, chemical

Amino Acids Play a Role in Flavor at Many Stages



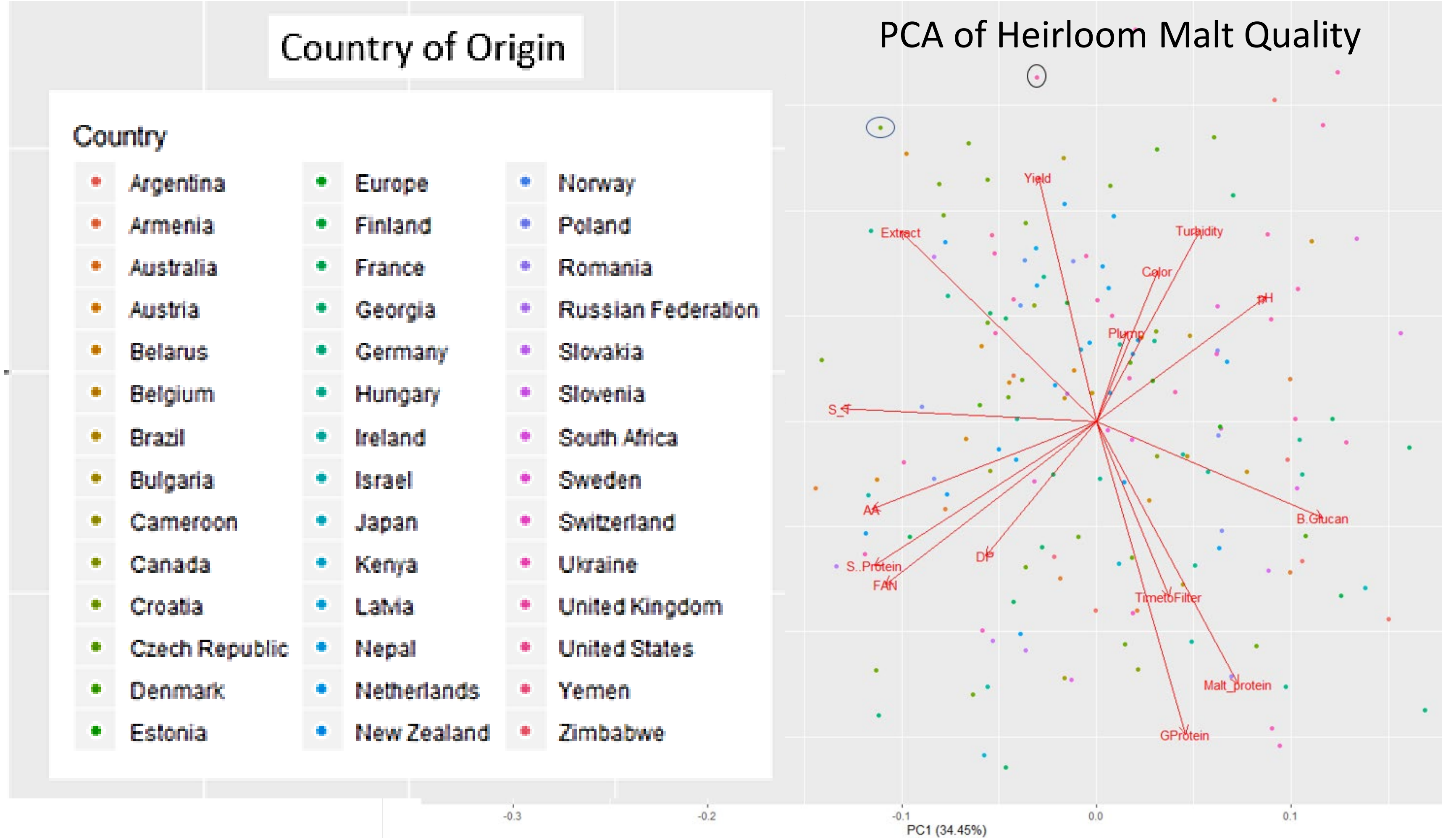
Ok – Variety Matters

But what do Heirloom lines mean in terms of breeding?

Analytically the heirloom varieties are certainly very different

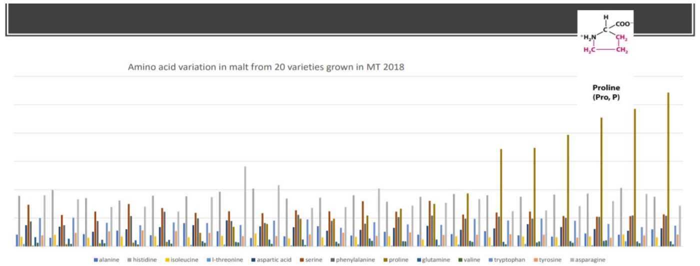
Next question, can the differences be associated to sensory data – and can we use associations to select for desired flavors?

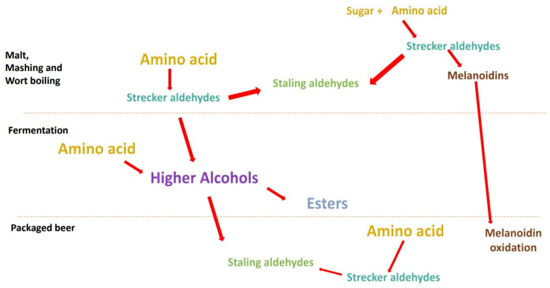
We still have many years of breeding ahead of us before having well adapted lines of high agronomic quality

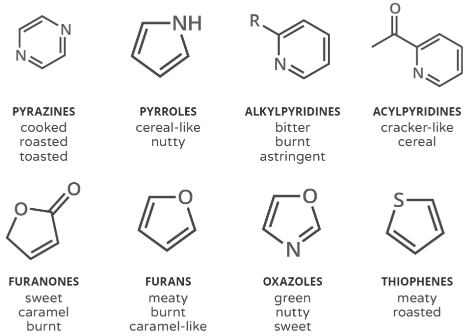


What about Modification and Procesing?

- Modification (ie malting environment) will further impact the chemical composition of malt
  - Starches vs. sugars and the composition of sugars
  - Balance of soluble and insoluble protein – and the composition of proteins and amino acids







Effect of Modification and Genotype on Beer Flavor

Genotype

Genetic population: Golden Promise, Full Pint, and 34 progeny
→Pilsner malt & beer

Modification

Full Pint & Copeland: Under, well, and overmodified malts were brewed

Findings:

- Variety and modification level individually impact beer flavor
- Contributions likely more important for delicate beer styles
- Worth pursuing for those with discerning preferences

Herb et al. 2017

And What About Terroir?

- The wine industry has made terroir known for grapes
- Does it matter for barley and beer?

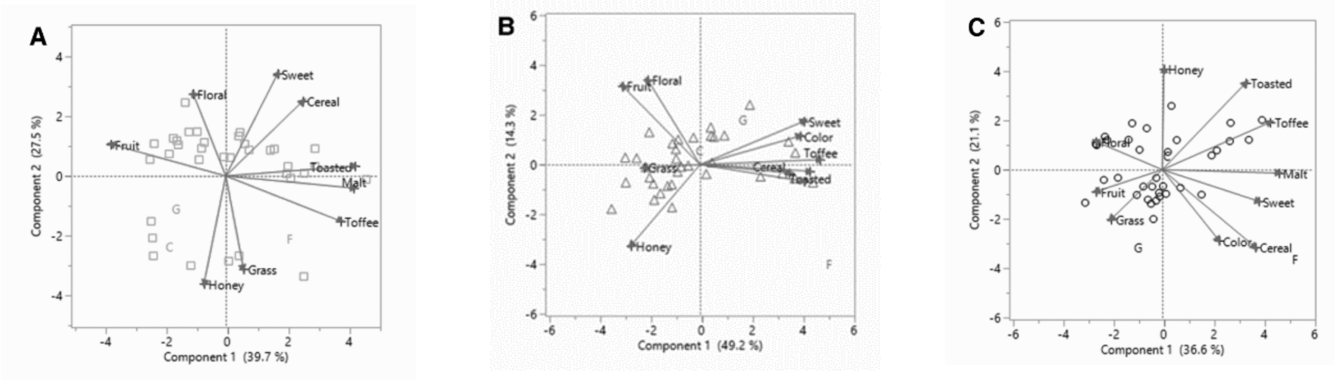
Variety and Terroir Impact on Beer Flavor

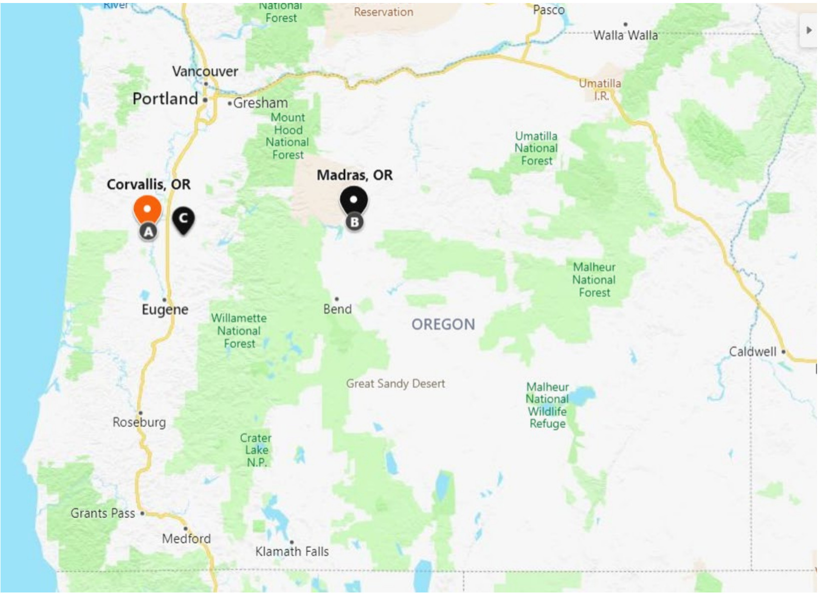
- Small-scale malting and brewing
  - sensory assessment of a large number of beers
- Golden Promise, Full Pint, and progeny, plus Copeland
  - grown at three locations in Oregon

Findings:

- Golden Promise: higher in fruity, floral, and grassy flavors.

  Full Pint: higher in malty, toffee, and toasted flavors
- Growing environment can have an effect → Terroir!





Corvallis, Lebanon, Madras OR

Herb et al. 2017

Terroir

- Malt brings a specific ionic composition to wort → terroir
- Mini Mash Experiment
  - Base malts from around the world
  - 200g fine grind malt w/ 1200g DI water
  - Held at 147-150F in thermos for one hour

	Canada	England	Germany	Wheat	Raw Barley
°P	10.1	10.6	10.6	9.5	2.6
SO_4	110.0	45.0	96.0	54.0	27.0
Cl	210.0	200.0	190.0	160.0	90.0
Ca	24.7	24.0	25.0	19.2	18.8
Mg	68.8	63.4	75.7	71.6	49.1
Na	40.6	7.2	23.6	10.7	10.8

*All units in ppm except gravity

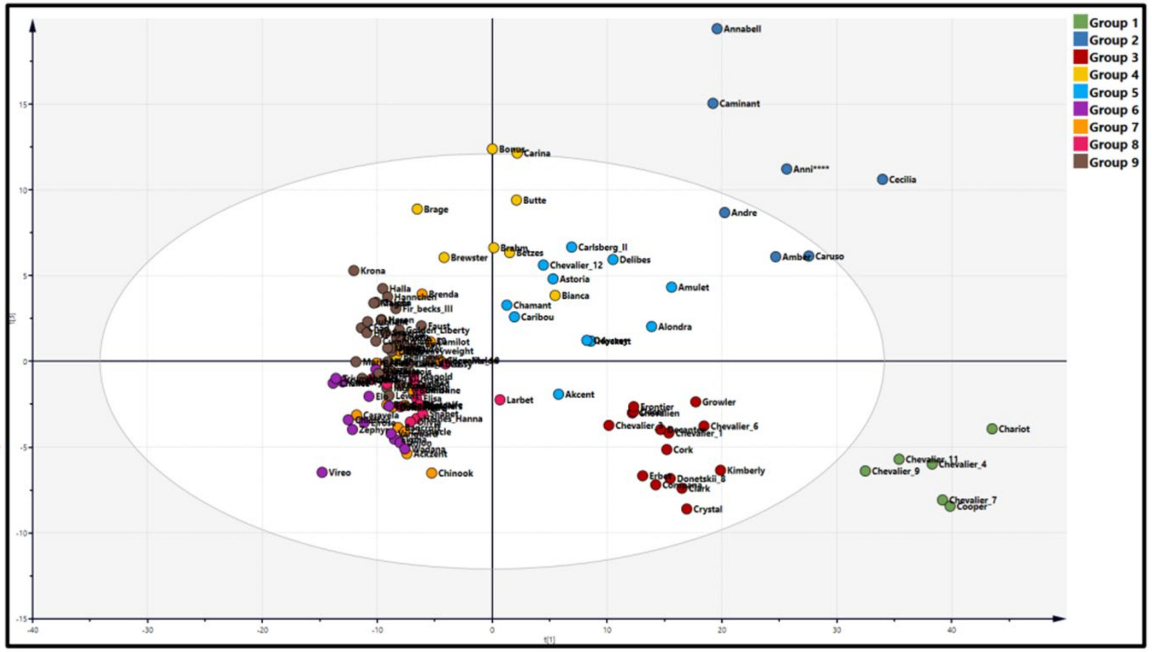
MSU Research to Come!

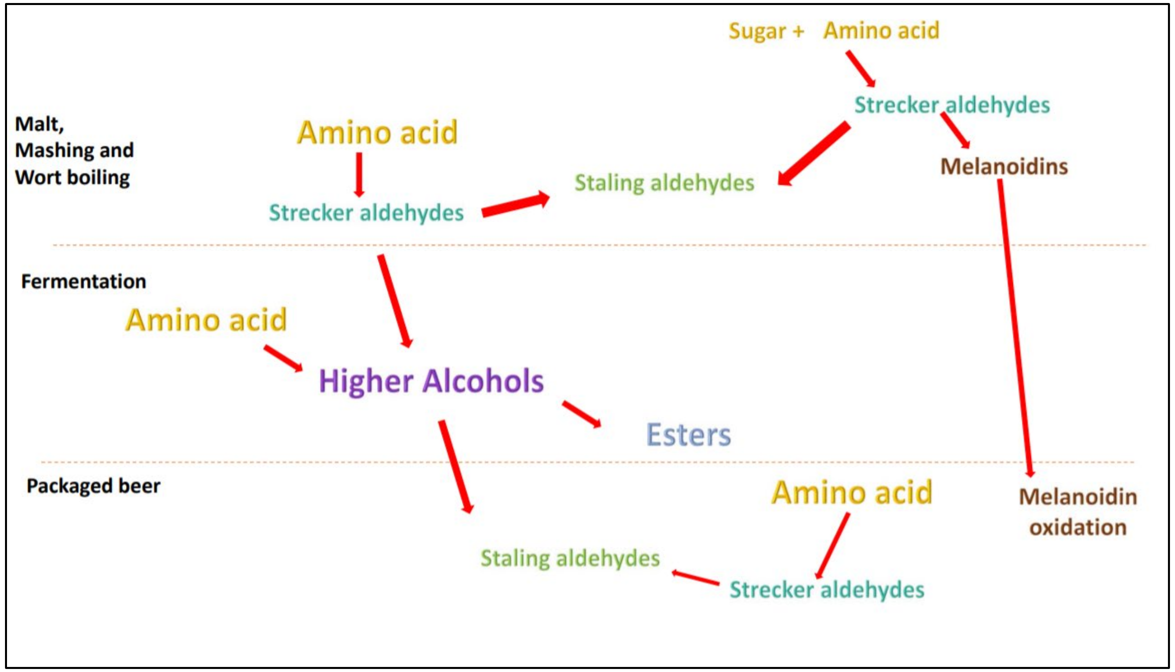
Evaluation of Heirloom & off-station malts for ionic composition
Summer 2021

WBC 2021, Justus: Ballast Point Brewing

What happens when we consider *interplay, all this with* kilning?

Terroir + variety + modification = unique compounds into the kiln & brewery!





Flavor production is a web – starting compounds will matter!

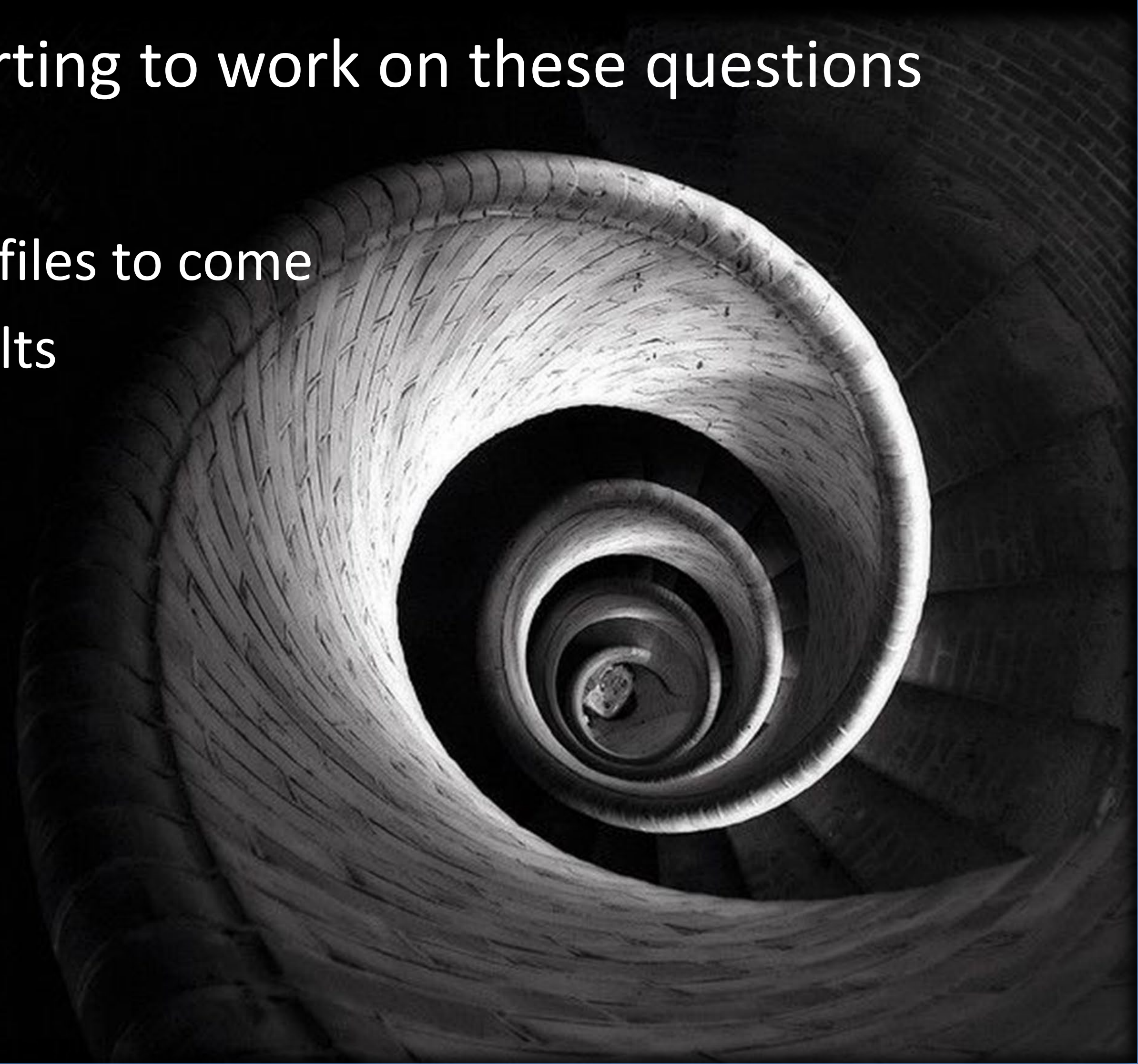
Malt Flavor Interplay – Current MSU Research

- Funded by the Brewers Association
- Building on heirloom: 300 varieties chemically profiled
  - 9 Unique groups identified – 4 represented here
  - 4 varieties x 3 modification levels x 3 kiln regimes
    - 36 unique malts

Buzz Odyssey Bianca Chalice	X	3 days germination 4 days germination 5 days germination	X	Lager malt Munich Malt Caramel Malt

Down the rabbit hole – we are only at the entrance!

- Researchers all over the world are starting to work on these questions
- MSU Current Research:
  - Correlations of chemical and sensory profiles to come
  - Brewing with unique chemical profile malts
- Future MSU research:
  - Amino acid composition (variety)
  - Ionic composition (terroir)

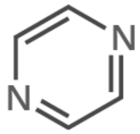


Thank You!
Questions?

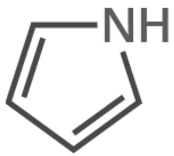
Hannah Turner
Hannah.turner2@montana.edu
Montana.edu/barleybreeding
Check out our learning center!

Maillard Products

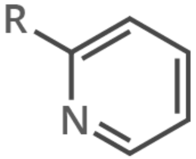
- – Almost all amino acids participate
- – Most reactive:
  - Glycine and Lycine
- – Maillard products will change based on what amino acids and sugars are available
  - Variety and modification



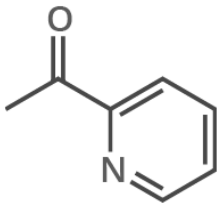
PYRAZINES
cooked
roasted
toasted



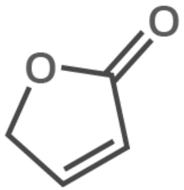
PYRROLES
cereal-like
nutty



ALKYLPYRIDINES
bitter
burnt
astringent

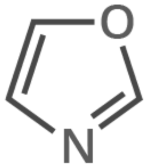


ACYLPYRIDINES
cracker-like
cereal



FURANONES
sweet
caramel
burnt

FURANS
meaty
burnt
caramel-like



OXAZOLES
green
nutty
sweet

THIOPHENES
meaty
roasted

Strecker Degradation

Amino acids directly forming Strecker Products:

-Alanine -Leucine
-Valine -Isoleucine
-Methionine -Phenylalanine

Indirect Degradation:
Other amino acids could still be acted on by a bacterium and indirectly add to Strecker degradations

Threshold values and aroma impressions of most important Strecker Degradation products present in beers

Compound	Threshold (mg $^{L-1}$)	Aroma Impression
2-methylpropanal	65 – 85	Grainy, varnish, fruity
2-methylbutanal	24 – 45	Almond, apple-like, malty
3-methylbutanal	45 -55	Malty, chocolate, cherry, almond
Methional	~4	Cooke potatoes, worty
Phenylacetaldehyde	~100	Hyacinth, flowery, roses
Benzaldehyde	~500	Almond, cherry, stone

[a]Thum et al., 1995; [b] Saison et al., 2009

Flavor from Esters and Higher Alcohols

Amino Acids Participating:

-Leucine
-Histidine
-Isoleucine
-Valine

Thresholds and aroma impressions of the most important esters and higher alcohols in beers

	Compound	Threshold (mg $^{L-1}$)	Aroma Impression
Esters	Ethyl acetate	20 - 30	Fruity, solvent-like
	Isoamyl acetate	0.6 - 2	Banana, pear
	Phenylethyl acetate	0.2 – 3.8	Roses, honey, sweet
	Ethyl hexanoate	0.2 - 0.23	Apple, fruity
	Ethyl caproate	0.17 – 0.21	Apple, aniseed
	Ethyl caprylate	0.3 - 0.9	Apple
	Ethyl octanoate	0.9 - 1.0	Apple, aniseed
Higher Alcohols	Propanol	6 – 800	Alcohol, solvent-like
	Isobutanol	80 -200	Alcolohol, solvent-like
	Isoamyl alcohol	50 – 70	Alcohol, banana, vinous
	Amyl alcohol	50 – 70	Alcohol, solvent-like
	2-Phenylethanol	40 – 125	Roses, sweet
	Tyrosol	1 - 200	Bitter, chemical

[a] Dufour and Malcorps, 1994; [b] Engan. 1981; [c] Meilgaard, 1975; [d] Engan,1972; [e]Reed, 1991; [f] Renger et al., 1992; [g] Olaniran et al., 2017; [h] Huges and Baxter, 2001.

Flavor Control in Kilning – Off-flavor: DMS

Dimethyl Sulfide

Sweetcorn, creamed corn, cabbage, canned/cooked vegetables

Threshold: 0.025 mg/l

- Comes from a sulfur-based organic compound produced in germinating grain
  - S-methyl methionine, SMM
- Six row lager malts and pilsner malts have the highest levels
  - Adjuncts like corn are also high.
- Off-flavor in most beer, but can play a role in flavor profile of some beers
  - Pale lagers, German and American pilsners, cream ales
- DMS can also come from wild yeast or bacterial contamination during fermentation

Control of DMS

Malting/Kilning

- Lower protein barley
- Lower modification
- Higher kiln temperatures
- Extended kilning
- Use of potassium bromate

Brewing

- Reduce usage of DMS style malts
- Watch for high moisture malts
- Store malts cool and dry
- Avoid over sparging
- Long vigorous boil
- Efficient crash cooling

Off-Flavor: Grainy/Husk like

Fresh wheat, grainy, harsh, green, raw grain

Threshold: 1-20 ug/l

- Caused by isobutyraldehyde in malt (also some other aldehydes)
- High levels in fresh malt
- High husk to endosperm ratio can promote
- Usually considered an off-flavor, but certain styles may have low levels
  - malt forward lagers

Control of Grainy/Husk Flavors

Malting/Kilning

- Use plump kernels (lower husk ratio)
- Avoid non-malting varieties (thin kernels)
- Ensure proper rest phase, at least two weeks post kiln

Brewing

- Avoid over crushing your malt
- Avoid long mashes
- Don’t sparge too hot water (over 168F)
- Don’t over sparge (don’t collect wort below 1.008 SG)
- Cold conditioning a beer can help get rid of some graininess

Malt Staling

- Malt is very stable below 6% moisture
  - Allowing malt to gain moisture promotes staling
  - Above 6% moisture malt is at risk for mold growth
  - Avoid rough treatment of malt
    - can cause breakage – promotes moisture uptake
  - Malt should always be stored in a cool dry location
    - manage for pests!

Variety

Variety	Modification	Kiln	Moisture	Extract (FG db)%	Color	Filtration Time	B-Glucan	Malt protein	S. Protein	S/T	FAN	AA	DP	Turbidity	pH
Odyssey	4 day	Lager	4.46	82.0	1.96	41	39	12.2	5.53	45%	249	92	169	2	6.0
Chalice	4 day	Lager	4.28	81.0	2.48	41	94	12.4	5.52	45%	238	74	134	3	5.9
Buzz	4 day	Lager	4.25	82.2	2.58	53	76	11.2	5.94	53%	280	124	153	6	5.8
Bianca	4 day	Lager	4.27	80.9	2.90	67	113	12.4	5.96	48%	263	82	154	43	5.8

Malt Modification

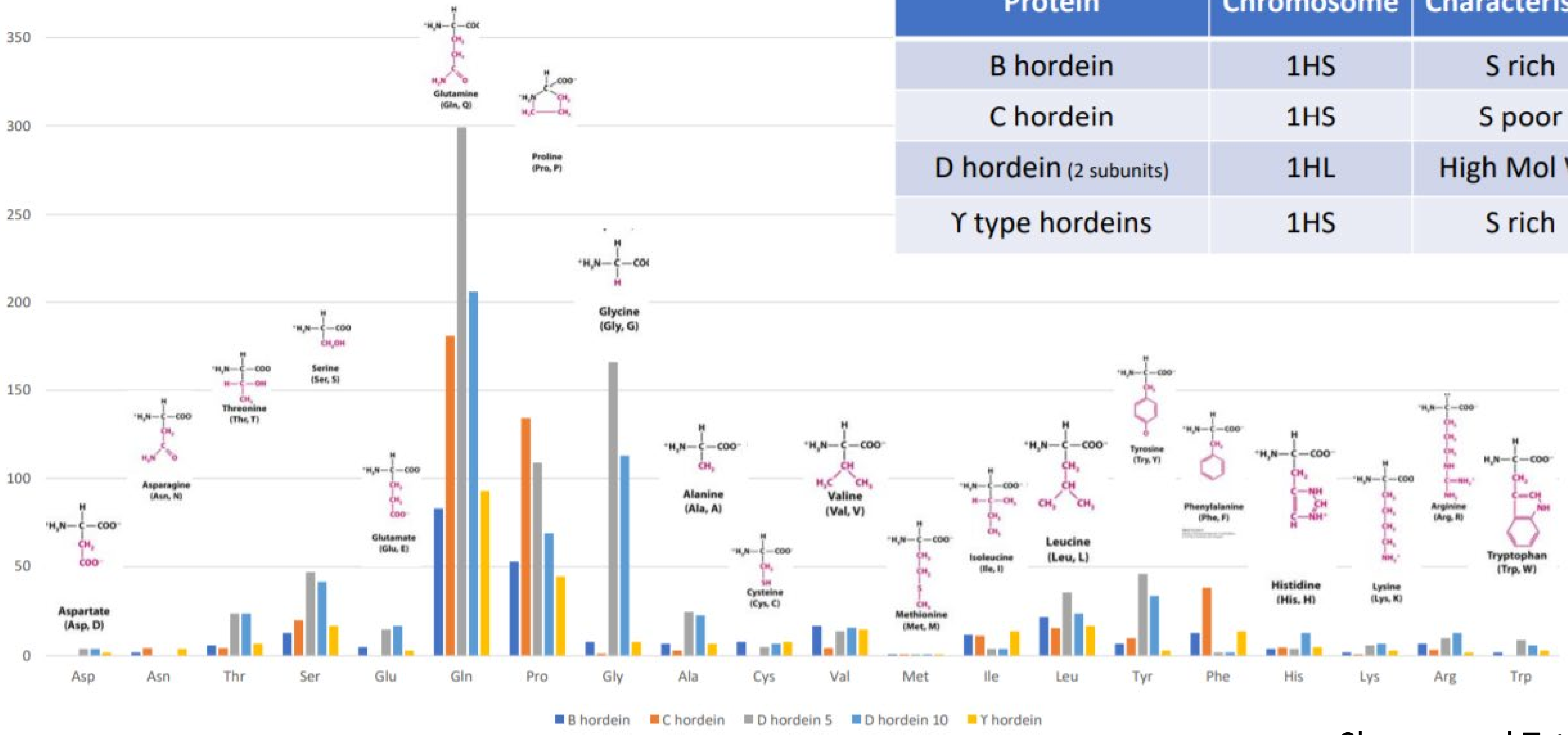
Variety	Modification	Kiln	Moisture	Extract (FG db)%	Color	Filtration Time	B-Glucan	Malt protein	S. Protein	S/T	FAN	AA	DP	Turbidity	pH
Odyssey	3 day	Lager	4.87	81.6	1.79	32	166	12.8	5.29	41%	241	85	162	4	5.9
Odyssey	4 day	Lager	4.46	82.0	1.96	41	39	12.2	5.53	45%	249	92	169	2	6.0
Odyssey	5 day	Lager	4.76	81.4	1.91	28	28	12.6	5.34	42%	239	109	182	3	5.9
Chalice	3 day	Lager	4.47	80.4	2.17	43	212	12.5	4.83	39%	206	71	126	7	5.9
Chalice	4 day	Lager	4.28	81.0	2.48	41	94	12.4	5.52	45%	238	74	134	3	5.9
Chalice	5 day	Lager	4.62	81.0	2.51	42	97	12.2	5.42	45%	236	90	146	7	5.8
Buzz	3 day	Lager	4.39	82.3	2.39	29	204	11.3	5.70	50%	250	103	146	8	5.8
Buzz	4 day	Lager	4.25	82.2	2.58	53	76	11.2	5.94	53%	280	124	153	6	5.8
Buzz	5 day	Lager	4.38	82.2	2.95	42	60	11.0	6.05	55%	273	139	158	10	5.7
Bianca	3 day	Lager	4.49	80.3	3.54	27	314	12.7	5.41	43%	237	73	158	57	5.8
Bianca	4 day	Lager	4.27	80.9	2.90	67	113	12.4	5.96	48%	263	82	154	43	5.8
Bianca	5 day	Lager	4.60	80.6	2.78	52	80	12.7	5.97	47%	260	100	166	29	5.8

Kilning

	Modification	Kiln	Moisture	Extract (FG db)%	Color	Filtration Time	B-Glucan	Malt protein	S. Protein	S/T	FAN	AA	DP	Turbidity	pH
AVE	3 day	Lager	4.6	81.1	2.5	33	224	12.3	5.3	43%	233	83	148	19	5.9
AVE	4 day	Lager	4.3	81.5	2.5	51	80	12.0	5.7	48%	257	93	152	14	5.9
AVE	5 day	Lager	4.6	81.3	2.5	41	66	12.1	5.7	47%	252	109	163	12	5.8
AVE	3 day	Munich	4.2	89.6	14.7	63	378	12.2	5.9	48%	168	38	30	14	5.6
AVE	4 day	Munich	3.9	89.2	17.2	44	149	12.3	6.3	49%	182	46	35	10	5.5
AVE	5 day	Munich	4.1	89.6	13.8	43	92	12.2	6.1	49%	199	59	51	9	5.5
AVE	3 day	Caramel 90C	4.5	87.2	17.6	86	387	12.0	5.6	46%	86	13	18	18	5.3
AVE	4 day	Caramel 90C	4.3	87.5	23.2	63	135	11.9	6.4	54%	94	15	17	9	5.3
AVE	5 day	Caramel 90C	4.4	87.2	20.4	70	67	11.9	6.4	54%	105	18	16	7	5.3

Amino Acids in Barley Storage Proteins

Protein	Chromosome	Characteristics
B hordein	1HS	S rich
C hordein	1HS	S poor
D hordein (2 subunits)	1HL	High Mol Wt
Y type hordeins	1HS	S rich



Shewry and Tatham, 1990