Barley Contributions to Beer Flavor

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Oregon State University

American Society of Brewing Chemists – Malt and Grain Symposium
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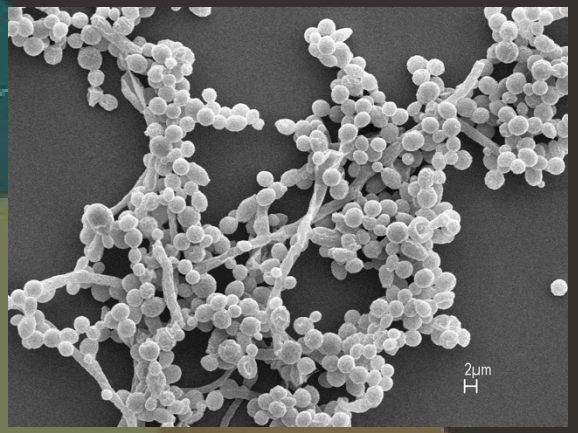
H_2O



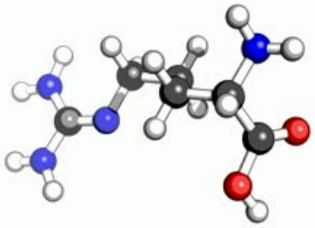
MALT

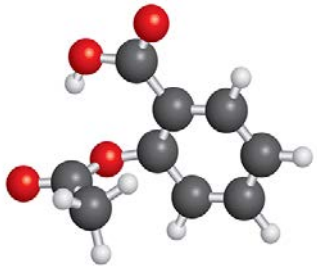
YEAST

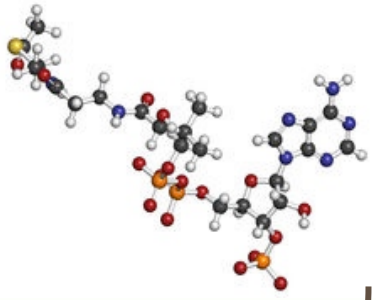
HOPS

Maillard Reaction (Heat + Time) / Oxidation & degradation (Heat + Time)

Amino acids + Reducing Sugars + Lipids







Barley

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Barley: genetic & environmental factors

All traits show GxE interactions, but depending on the trait there may be a larger G or E effect. These effects are shown below:

Amino Acids

- Protein content (genetic/environment)
- Protein composition (genetic)
  - Specific amino acid
- Dormancy (genetic)
- Germination Energy (genetic)
- Amylase & Protease (genetic)

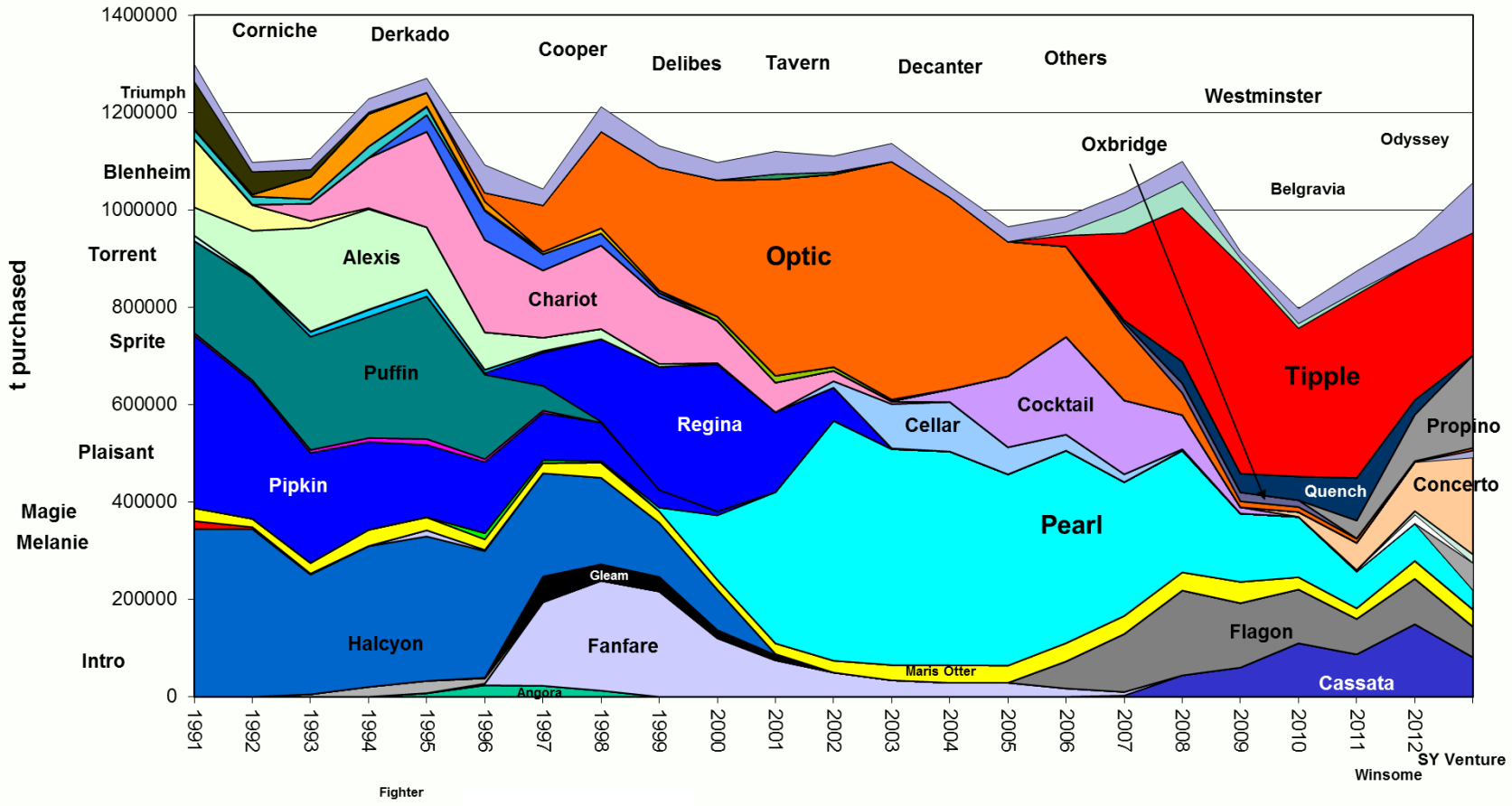
Reducing Sugars

- Starch content (genetic/environment)
- Starch composition (genetic)
  - Amylose: Amylopectin ratio
  - Sucrose, glucose, fructose
- Diastatic power (genetic)

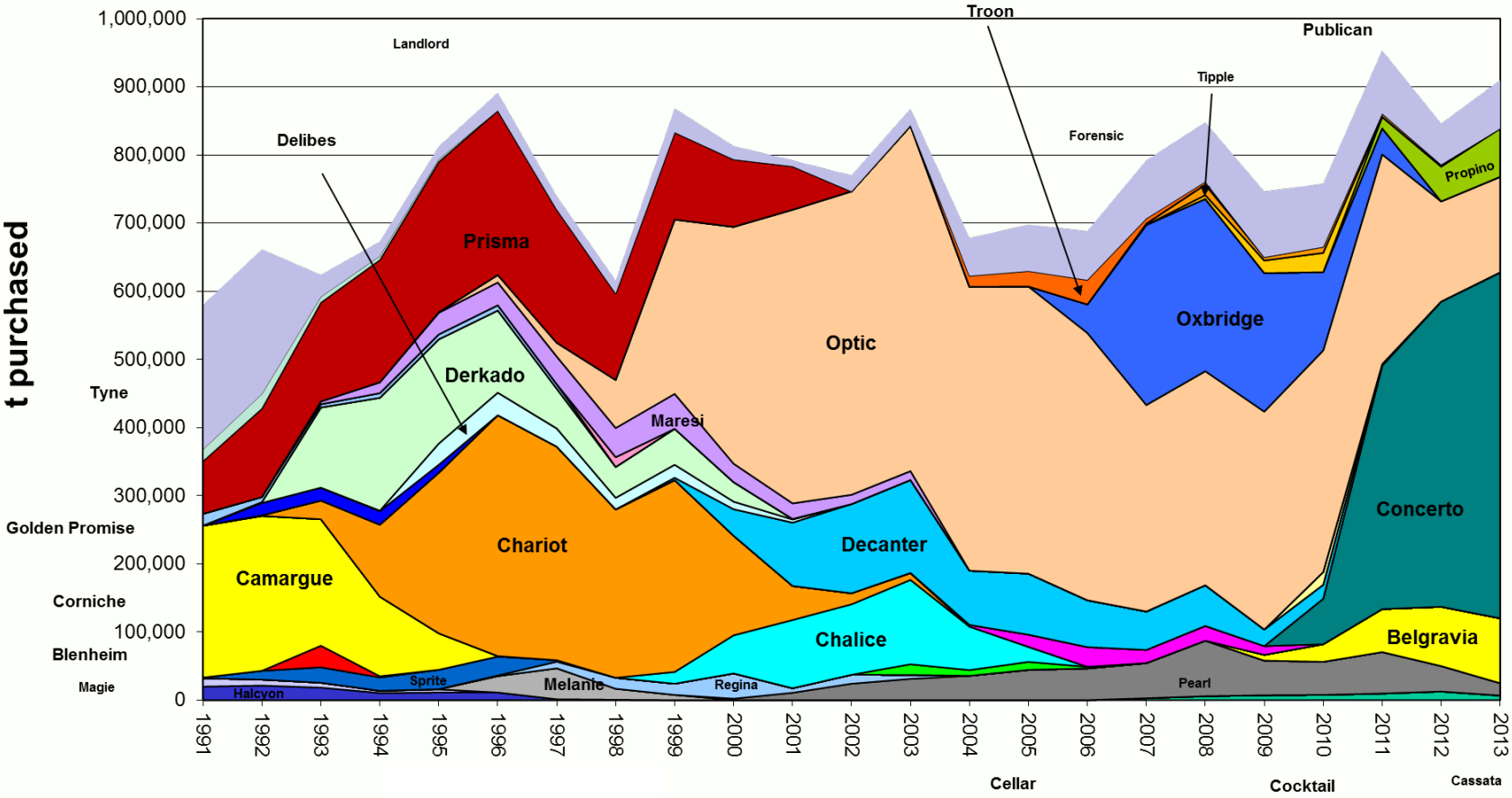
Lipids

- Lipid content (genetic/environment)
- Lipid composition (genetic)

English Malting Barley Purchases



Scottish Malting Barley Purchases



Objectives

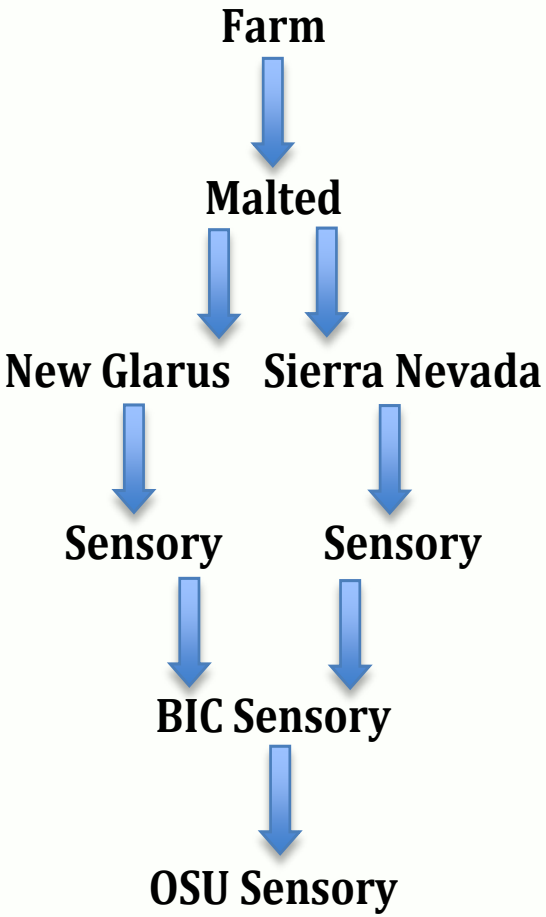
- Determine if barley variety is a significant contributor to beer flavor. If variety is significant, determine
  - factors that influence the barley contributions to beer flavor.
  - if selection pressures in modern breeding programs have indirectly selected against barley flavor.

Are there flavor differences between varieties?

Phase I: 3x – Varietal flavor differences

- Three varieties
  - Full Pint; Klages; CDC Copeland
  - 40 meters strips
  - Grown in replication
  - Harvest 2014 in Lebanon, OR

- Malted at the Canadian Malting Barley Technical Center (CMBTC)
- Brewed at New Glarus Brewing Co. and Sierra Nevada Brewing Co.
- Beer sensory at NGBC, SNBC, Barley Improvement Conference, Oregon State University, and Corvallis Brewing Supply



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Difference Analysis: triangle test at Oregon State University

Stella/Highlife Control	**NG: FP/KG**	**NG: CP/KG**	**NG: FP/CP**	**SN: FP/CP**	**SN: KG/FP**	**SN: KG/CP**
45/50	23/50	24/50	19/50	28/50	19/50	23/50
P=0.000	P=0.0379	P=0.0196	P=0.2703	P=0.0007	P=0.2703	P=0.0379
Different	Different	Different	Not Different	Different	Not Different	Different
Comments from assessors who correctly identified odd sample in triangle test	B-damascence Diacetyl Bananas Lightstruck Toasted	Cheesy Pungent Diacetyl Subtle Toasted Coffee		Chocolate Diacetyl DMS Less aroma Malty Sweaty		Astringent DMS Diacetyl Mouthfeel Less aroma Malty Weak

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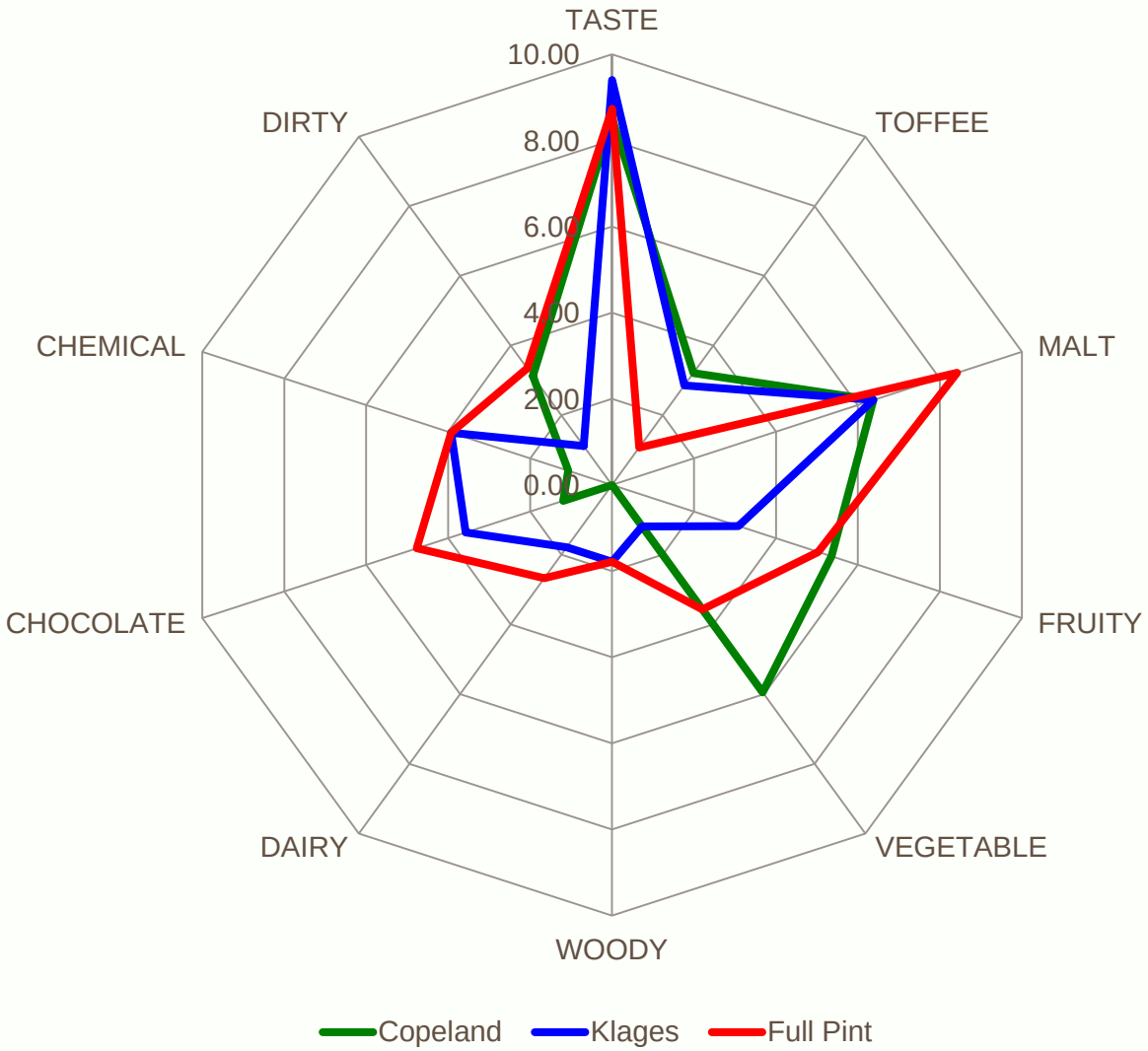
Descriptive Analysis: Combined free-choice profiling from the Barley Improvement Conference, Oregon State University, and Corvallis Brew Supply



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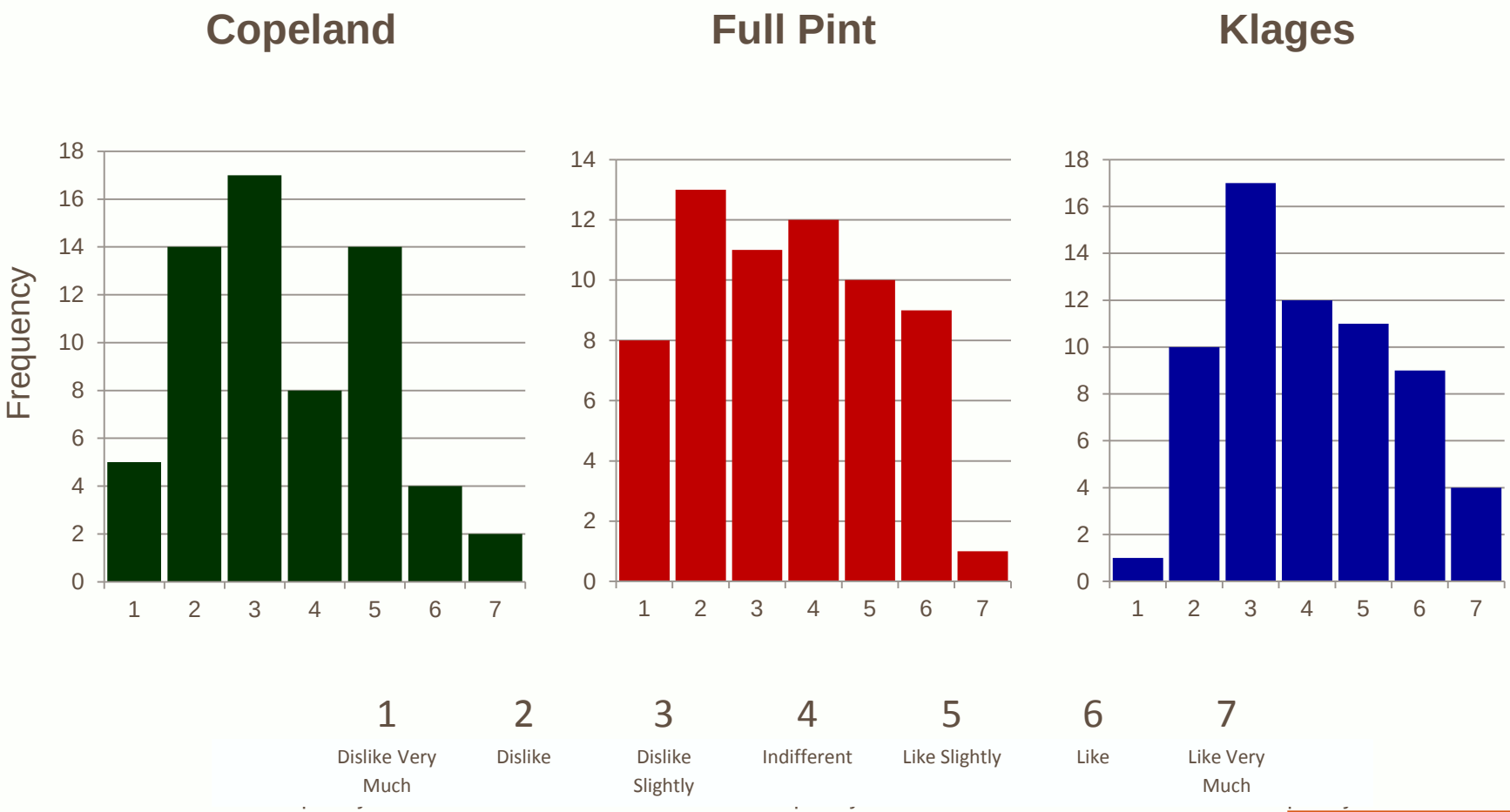
Consumer Analysis: Combined preference rating of CDC Copeland, Full Pint, and Klages from Barley Improvement Conference and Corvallis Brew Supply



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Malt Quality

Variety	Friab. (%)	Ext. (%)	S/T Ratio	β-glucans (ppm)	DP (˚L)	Color	FAN (mg/L)
Full Pint	52.5	78.5	38.2	397	155	1.7	177
Klages	74	80.2	44.3	385	118	1.78	198
CDC Copeland	89.8	81.8	47.8	103	125	1.75	198

Phase I: 3x - Results

- **4 / 6 beer samples were significantly different**
  - 2 NGBC (FP/KG & CP/KG)
  - 2 SNBC (FP/CP & KG/CP)
  - Moderate diacetyl detected in samples

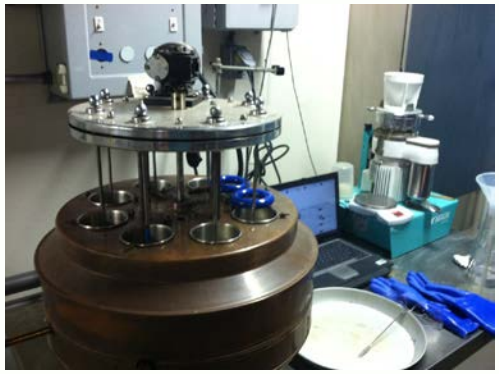
- **Flavor ranking**
  - Klages = highest = Basic taste
  - Full Pint = highest = Malty, Chocolate
  - CDC Copeland = highest = Vegetable, Fruity

- **Variety preference**
  - Klages had the highest preference rating
  - CDC Copeland and Full Pint similar

What factors influence barley contributions to beer flavor?

Phase II: 3x3 – Influences on barley beer flavor

- 3 varieties:
  - Full Pint; Klages; AC Metcalfe
- 3 locations:
  - Corvallis, OR
  - St. Paul, MN
  - Saskatoon, CA
- Malted at Rahr



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Wort analytics (GC-MS & GC-O) at Sierra Nevada Brewing Co.

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Wort sensory at Sierra Nevada Brewing Co.

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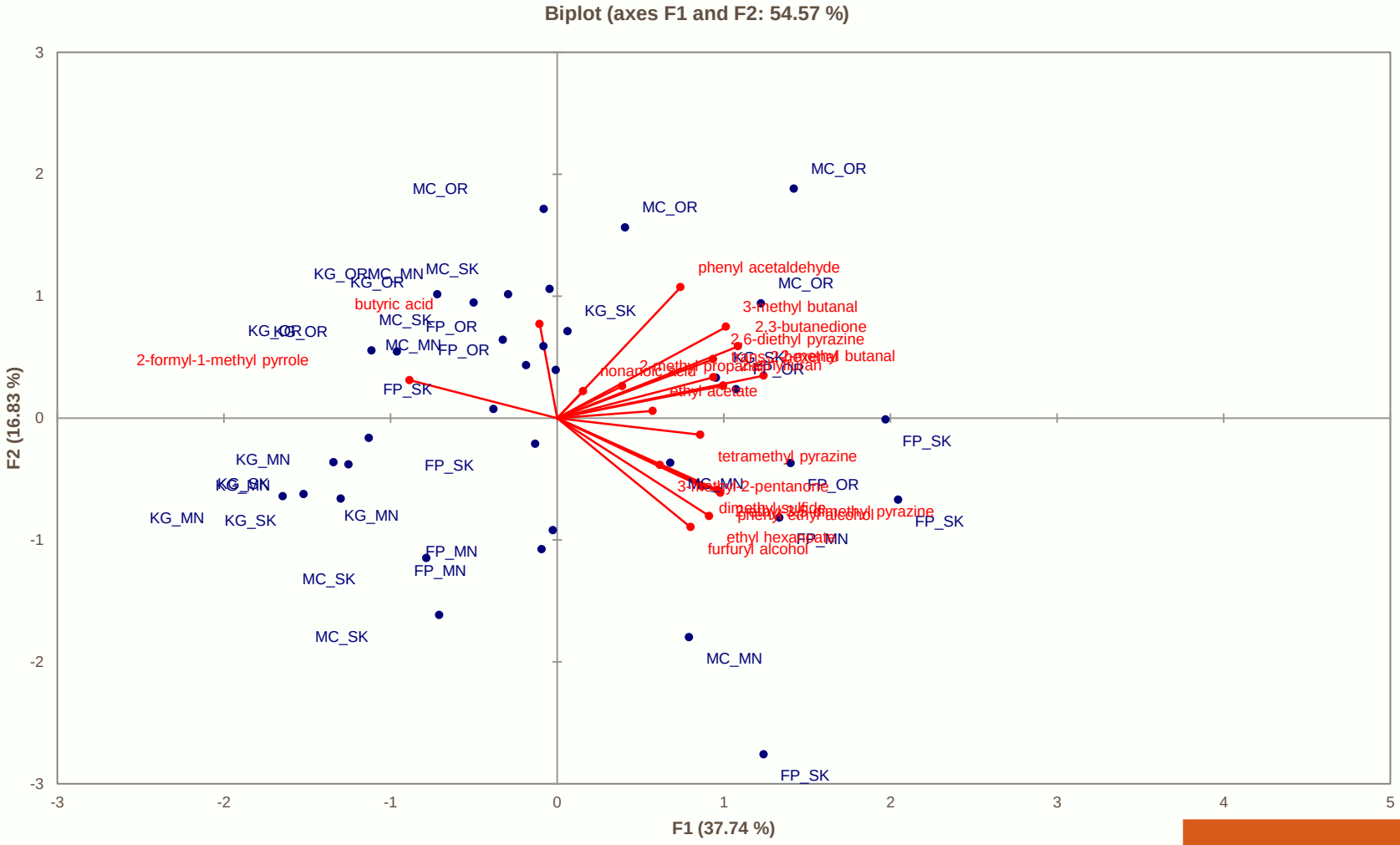
Phase II: 3x3 – Aroma Compound Results

- **ANOVA:**
  - **37 / 51** aroma compounds measured had significant effects
    - Variety; environment; G x E
  - **11 / 51** aroma compounds had significant variety and environment effects
  - **6 / 51** aroma compounds had significant variety x environment interactions

- **LSMeans Student's t-test:**
  - **Variety effects:**
    - 24 / 33 highest in Full Pint
    - 8 / 33 highest in AC Metcalfe
    - 1 / 33 highest in Klages
  - **Environment effects:**
    - 13 / 16 highest in Oregon, USA
    - 3 / 16 highest in Minnesota, USA
    - 0 / 16 highest in Saskatchewan, CA

Aroma Compound	Odor Type	Geno	Enviro	G x E	Run	Variety	Environment
2,3-butanedione	Buttery	X	X	X		FP,MC,KG	OR,SK,MN
2-ethyl-3,5-dimethyl pyrazine	Nutty	X	X			FP,MC,KG	MN,SK,OR
furan	Ethereal	X	X			FP,MC,KG	OR,SK,MN
trans-2-hexenal	Green	X	X			MC,FP,KG	OR,SK,MN
phenylacetaldehyde	Green	X	XX			MC,FP,KG	OR,SK,MN
2-formyl-1-methyl pyrrole	Roasted	X				KG,FP,MC	MN,OR,SK
2-methylfuran	Chocolate	X				MC,FP,KG	SK,MN,OR
4-vinyl phenol	Phenolic	X				MC,FP,KG	MN,OR,SK
dimethyl styrene	Phenolic	X				FP,MC,KG	OR,SK,MN
ethyl decanoate	Waxy	X				FP,MC,KG	MN,SK,OR
ethyl dodecanoate	Waxy	X				FP,MC,KG	MN,SK,OR
ethyl hexanoate	Fruity	X				FP,MC,KG	MN,SK,OR
ethyl octanoate	Waxy	X				FP,MC,KG	MN,OR,SK
furfural	Bready	X				FP,MC,KG	SK,OR,MN
methyl mercaptan	Sulferous	X				FP,MC,KG	SK,OR,MN
propanal	Ethereal	X				FP,MC,KG	MN,SK,OR
tetramethyl pyrazine	Nutty	X		X		FP,MC,KG	MN,OR,SK
2-ethylfuran	Chemical	XX	X			FP, MC, KG	OR,SK,MN
2-methyl butanal	Chocolate	XX	X			FP, MC,KG	OR,SK,MN
2-methylpropanal	Spicy	XX	X			MC,KG,FP	MN,OR,SK
ethyl acetate	Ethereal	XX	X	XX		FP,KG,MC	OR,SK,MN
propanol	Alcoholic	XX	X			FP, MC, KG	OR,SK,MN
3-methyl butanal	Aldehydic	XX	XX			FP,MC,KG	OR,SK,MN
furfuryl alcohol	Bready	XX	XX			FP,MC,KG	MN,SK,OR
2,6-diethyl pyrazine	Nutty	XX		XX		MC,FP.KG	OR,SK,MN
3-methyl-2-pentanone	Peppermint	XX				FP,MC,KG	MN,SK,OR
butyric acid	Cheesy	XX				MC,KG,FP	MN,OR,SK
dimethyl disulfide	Sulferous	XX				FP,MC,KG	MN,SK,OR
dimethyl sulfide	Sulferous	XX				FP,MC,KG	MN,SK,OR
dmts	Alliacious	XX				FP,MC,KG	SK,OR,MN
nonanoic acid	Waxy	XX		XX		FP,KG,MC	OR,SK,MN
octanoic acid	Fatty	XX				FP,MC,KG	OR,SK,MN
phenyl ethyl alcohol	Floral	XX				MC,FP,KG	MN,SK,OR
4-methyl-2-pentanone	Green		X	X		MC,KG,FP	OR,MN,SK
hexanal	Green		X			MC,KG,FP	OR,SK,MN
2-acetyl furan	Balsamic		XX			KG,MC,FP	OR,SK,MN
hexanoic acid	Fatty		XX			KG,MC,FP	OR,SK,MN
2,5-dimethyl furan	Meaty				X	MC,KG,FP	OR,SK,MN
2-methyl-1,3-butanedione	Buttery					KG,FP,MC	OR,MN,SK
2-vinyl furan	Phenolic					MC,FP,KG	MN,OR,SK
acetic acid	Acidic					FP,MC,KG	SK,OR,MN
dl-limonene	Citrus				XX	MC,FP,KG	MN,OR,SK
gamma nonalactone	Coconut					FP,MC,KG	MN,OR,SK
hexanol	Herbal					FP,MC,KG	SK,OR,MN
isoamyl butyrate	Fruity				X	MC,FP,KG	MN,OR,SK
methyl pyrazine	Nutty					FP,MC,KG	SK,MN,OR
perillene	Woody				XX	MC,FP,KG	MN,SK,OR
phenyl ethyl acetate	Floral					FP,MC,KG	MN,SK,OR
styrene	Balsamic					KG,MC,FP	MN,SK,OR
xylene isomer #1	Sweet					KG,FP,MC	MN,OR,SK
xylene isomer #2	Sweet					KG,FP,MC	MN,OR,SK

Phase II: 3x3 – Results: Biplot of Principle Component Analysis of Combined Variety, Environment, and Aroma Compounds



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Phase II: 3x3 – Sensory Results

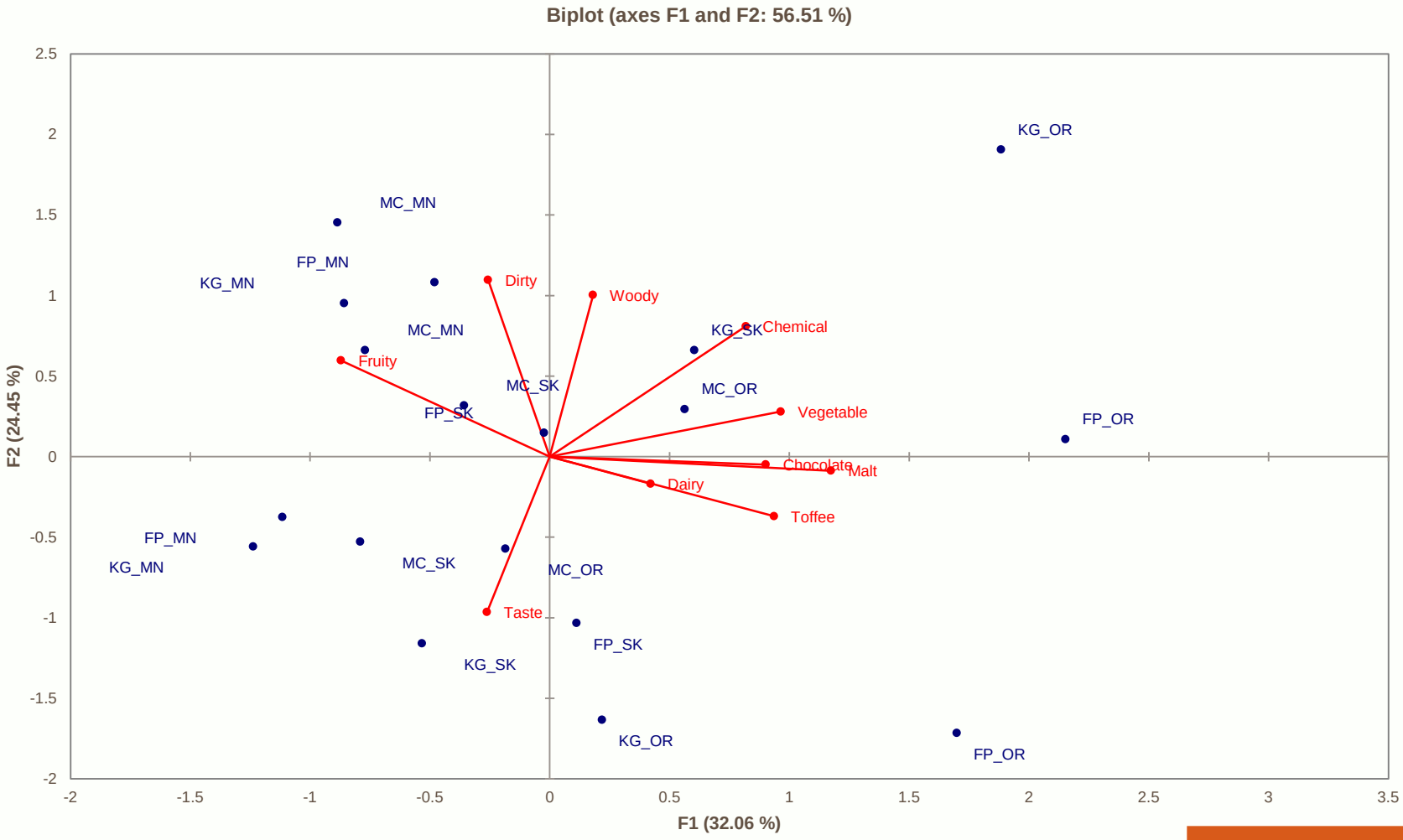
Sensory Evaluations

- Free-choice profiling
- 10 trained panelist from Sierra Nevada Brewing Co.
- Significant variety, environment and interaction effects detected

Sensory: ANOVA

Flavor	Variety	Environment	G X E	Rep
Total				
Taste	X			
Malt	X	X	X	
Fruity	X	X	X	
Chocolate	X	X		X
Toffee	X	X	X	X
Vegetable	X	X		
Dairy		X		
Woody	X			
Chemical		X		

Phase II: 3x3 - Results: Biplot of Principle Component Analysis of Combined Variety, Environment, and Sensory Evaluations



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Phase II: 3x3 - Correlation: Detection of aroma compounds in sensory?

Aroma Compounds

Flavor	Aroma Compound	Top Variety	Top Environment
Buttery	2, 3-butanedione	Full Pint	Oregon
Cheesy	Butyric acid	Metcalfe	Minnesota
Waxy	Nonanoic acid	Full Pint	Oregon
Nutty	2-ethyl-3,5-dimethyl pyrazine	Full Pint	Minnesota
Nutty	2,6-diethyl pyrazine	Metcalfe	Oregon
Nutty	2-acetyl furan	Klages	Oregon
Bready	Furfuryl alcohol	Full Pint	Minnesota
Roasted	2-formyl-1-methyl pyrrole	Klages	Minnesota
Chocolate	2-methyl butanal	Full Pint	Oregon
Spicy	2-methyl propanal	Metcalfe	Minnesota
Green	phenyl acetaldehyde	Metcalfe	Oregon
Floral	phenyl ethyl alcohol	Metcalfe	Minnesota
Fruity	ethyl hexanoate	Metcalfe	Minnesota
Ethereal	ethyl acetate	Full Pint	Oregon
Aldehyde	3-methyl butanal	Full Pint	Oregon
Chemical	2-ethyl furan	Full Pint	Oregon
Sulferous	dimethyl sulfide	Full Pint	Minnesota

Sensory

Flavor	Top Variety	Top Environment
Taste	Klages	Saskatchewan
Dairy	Full Pint	Oregon
Malty	Full Pint	Oregon
Toffee	Full Pint	Oregon
Roasted	Full Pint	Oregon
Chocolate	Full Pint	Oregon
Fruity	Metcalfe	Minnesota
Vegetable	Metcalfe	Oregon
Chemical	Klages	Oregon
Dirty	Metcalfe	Minnesota

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What does this mean?

- **Variety significantly influences certain flavor compounds**
  - **Genetics and particular compound(s) composition**
    - Indirect selection for amino acid composition → aroma compounds
  - **Genetics and compound(s) content**
    - Higher protein → More amino acids → Increased Maillard products
    - Higher starch → More reducing sugars → Increased Maillard products
- **Environment significantly influences certain flavor groups**
  - Nutrients, day length, temperature, moisture, management, etc.
  - More Nitrogen (applied & residual) → Higher protein
- **Interaction (G X E)**
  - Some varieties are more nitrogen sensitive than others

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How do we apply this in a breeding program?

Phase III: Exotic Beer Flavor - GWAS

Genetically diversity panel subset from USDA barley world core, harvested 2012 in Corvallis, OR

- 174 genetically diverse lines from around the world
- Germplasm profiling: agronomic performance, chemical analysis of wort, GC-MS, GC-O of wort, amino acid analysis, and wort sensory
- Nano-brewing & beer sensory
- Genome-wide Association Studies (GWAS) on genetics of beer flavor

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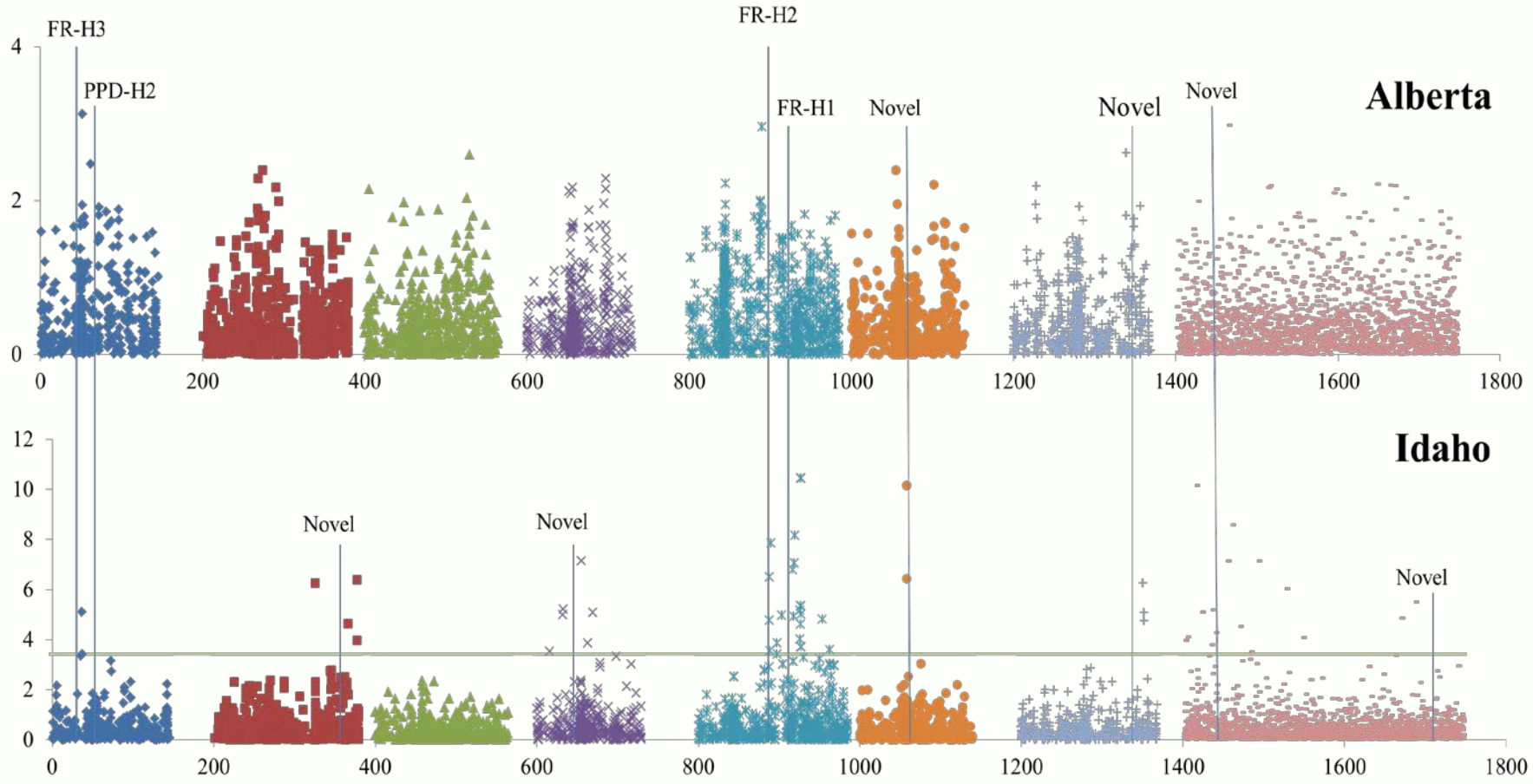

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Phase IV: Biparental Populations

Oregon Promise (Full Pint x Golden Promise)

Maris Beaver (Full Pint x Maris Otter)

Full Stein (Full Pint x Violetta)

- Doubled haploid populations of locally adapted material by renowned flavor varieties
- Measure agronomic performance, malting quality, nano-brew.
- Flavor compounds?????
- Quantitative Trait Locus (QTL) mapping for all traits to discover underlying genes.

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Selection for high flavor intensities in new malting barley varieties

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Acknowledgments

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  - Dr. Mary Cluskey
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  - Meghan Peltz
  - Daniel Vollmer
  - Daniel Sharp
  - Araby Belcher
  - Brigid Meints
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  - New Glarus Brewing Co.
  - Summit Brewing Co.
  - Russian River Brewing Co.
  - Bells Brewing Co.
  - Firestone-Walker Brewing Co.
- **Cooperators**
  - Rahr Malting Co.
  - Canadian Malting Barley Technical Center
  - Canadian Grain Commission

USDA United States Department of Agriculture National Institute of Food and Agriculture

Triticeae CAP Coordinated Agricultural Project

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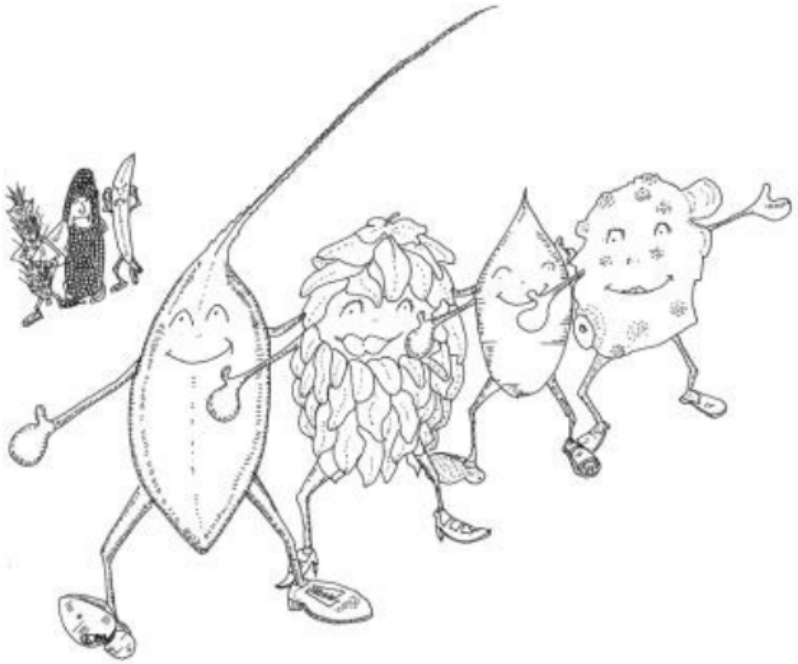
Think Barley



Drink Barley

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