

**Can analytical and sensory assessment
be used to accurately predict the sensory
characteristics of hops in finished beers?**

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Overview

- Background
- Our approach
- Hop data and insights
- Beer data and insights
- Hop blending – ‘show me the way to Amarillo’
- Conclusions



Hops - the current challenges

- Technical considerations
 - Huge choice – where do you start?
 - Format – whole hops, pellets, concentrates, extracts
- Financial considerations
 - Poor harvests – reduced supply
 - Expensive propriety varieties

So what can we do?

Hop blending

- More art than science
- Based on experience – hop merchant and brewer
- Several recommended substitute hops
- Difficult to predict accurately

Our approach

- Identify and source a range of aroma hops
 - New and traditional varieties
 - From several geographical regions
- Assess hops - sensory profiling and analytically
- Pilot brews – single hop brews, late addition
- Analyse data and use it to see if it can predict the effect on blending
- Brew blends to match a specific aroma hop variety
- Assess blended hop beer using our expert sensory panel

Hop choice

- Identify a range of hops to investigate: 14 selected in total
- New and established varieties
- From various regions in the world (UK, Europe, US, Aus)

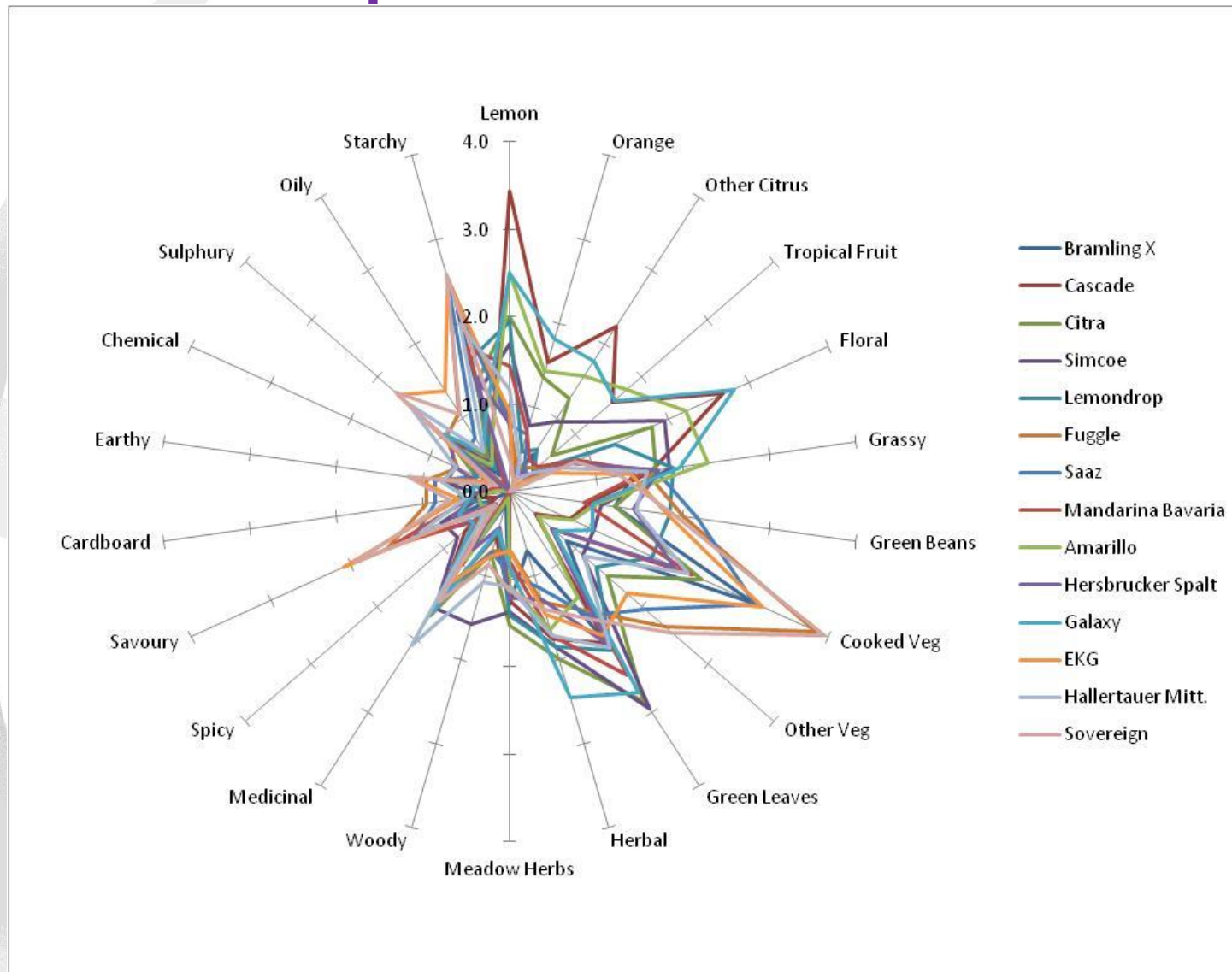
Hop variety	
Amarillo hop pellets	Hersbrucker Spat hop pellets
Bramling Cross hop pellets	Lemondrop hop pellets
Citra hop pellets	Mandarina Bavaria hop pellets
East Kent Golding hop pellets	Sovereign 2014 hop pellets
Fuggle hop pellets	US Cascade hop pellets
Galaxy hop pellets	Saaz hop pellets
Hallertauer Mittelfruh hop pellets	Simcoe 2013 Harvest US hop pellets

Hop tea sensory data

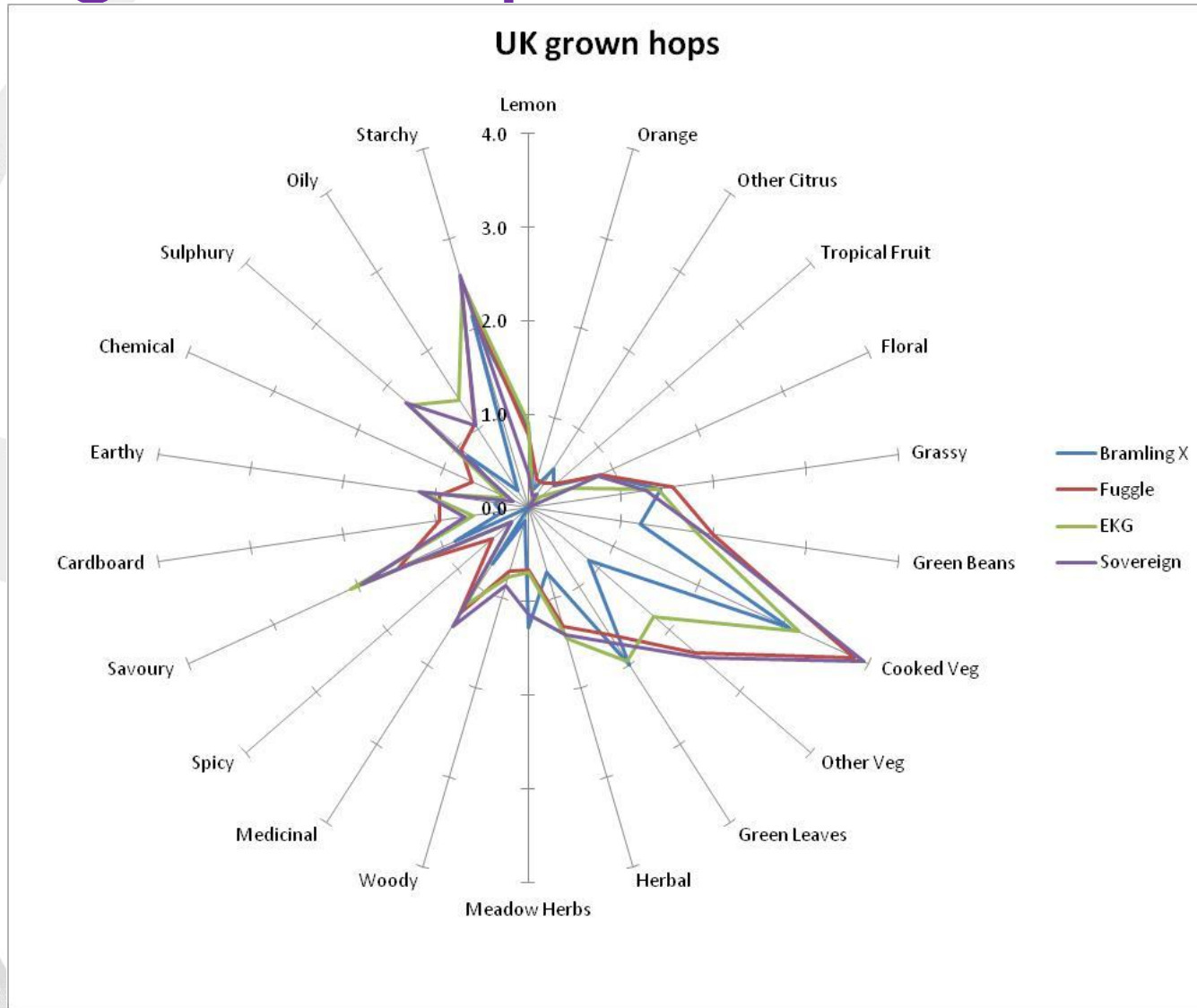
- Hop teas prepared using 5g hop pellets in 2L boiling water left to cool to room temperature
- Expert panel agreed the sensory attributes to be used
- 22 attributes identified and used to assess each hop, scale 0-9

Hops sensory data

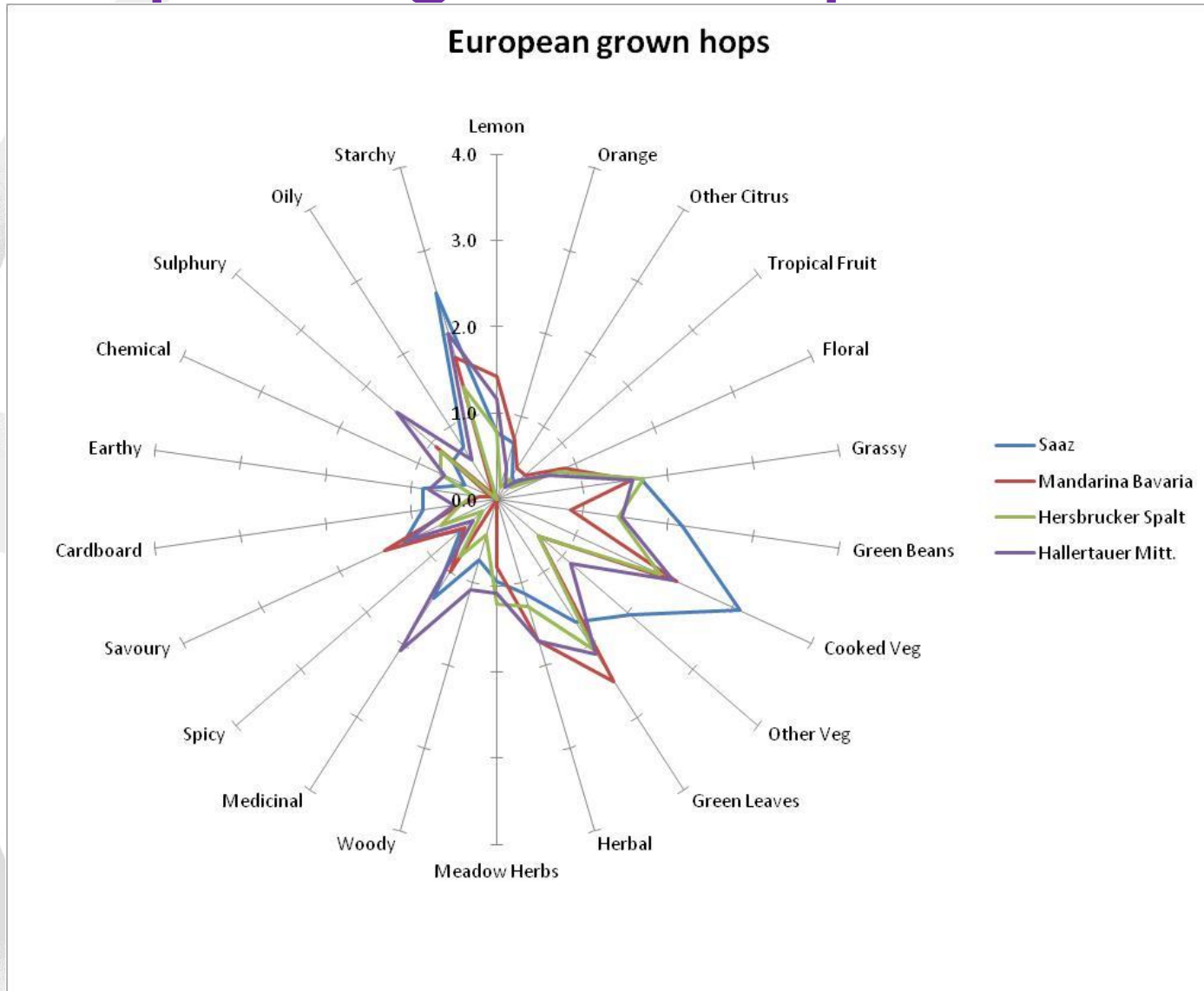
All 14 hop teas



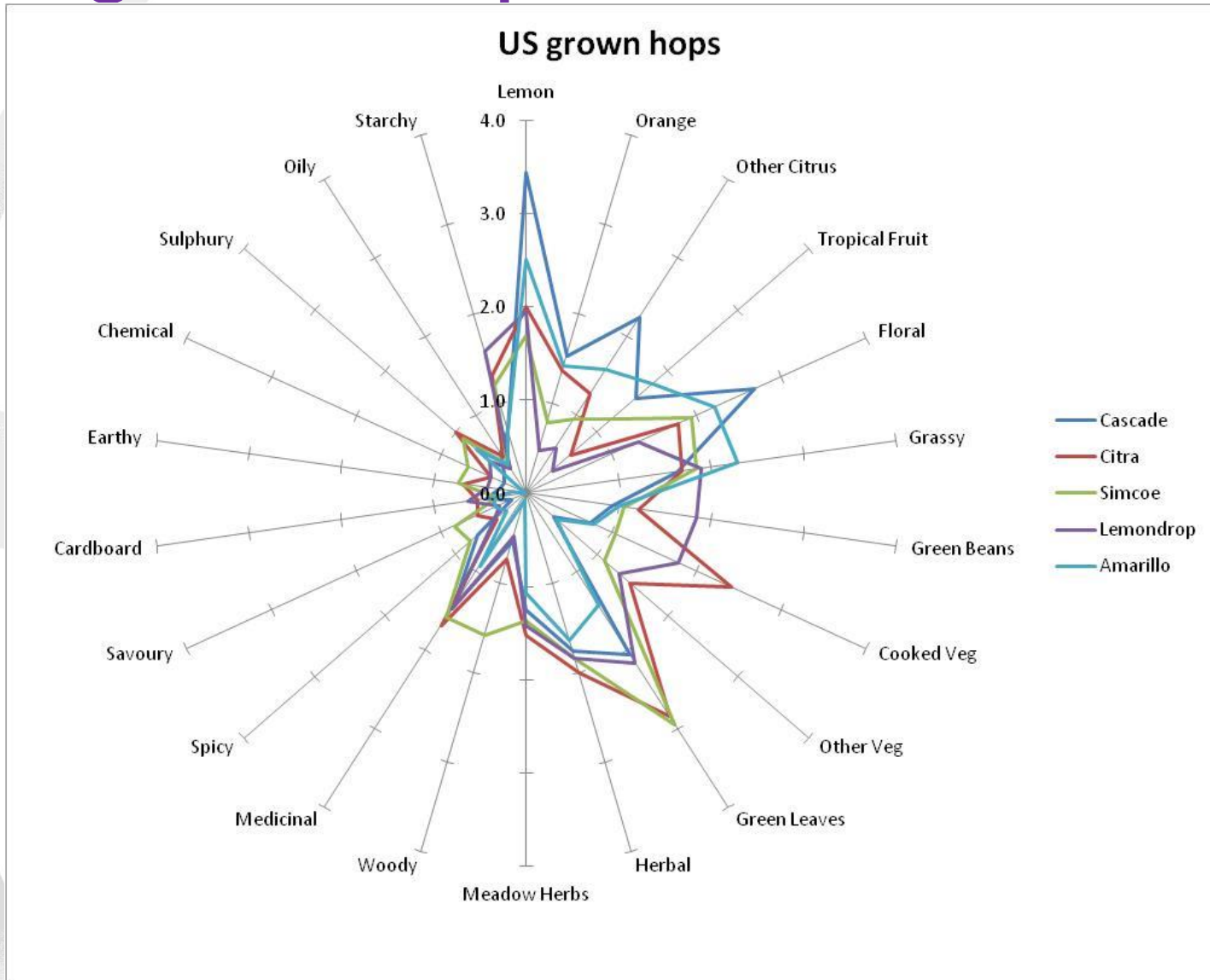
UK grown hops



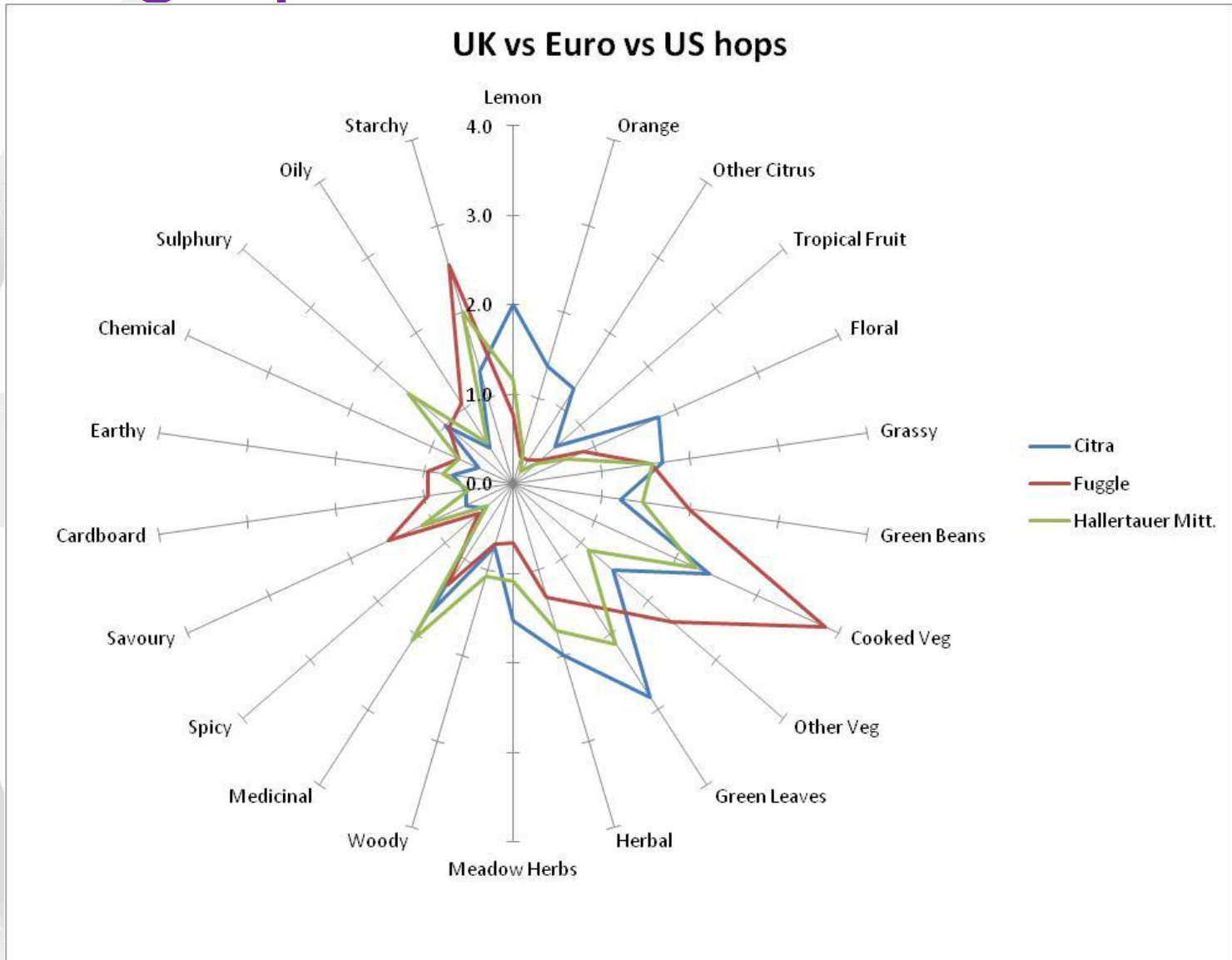
European grown hops



US grown hops



Geographical differences

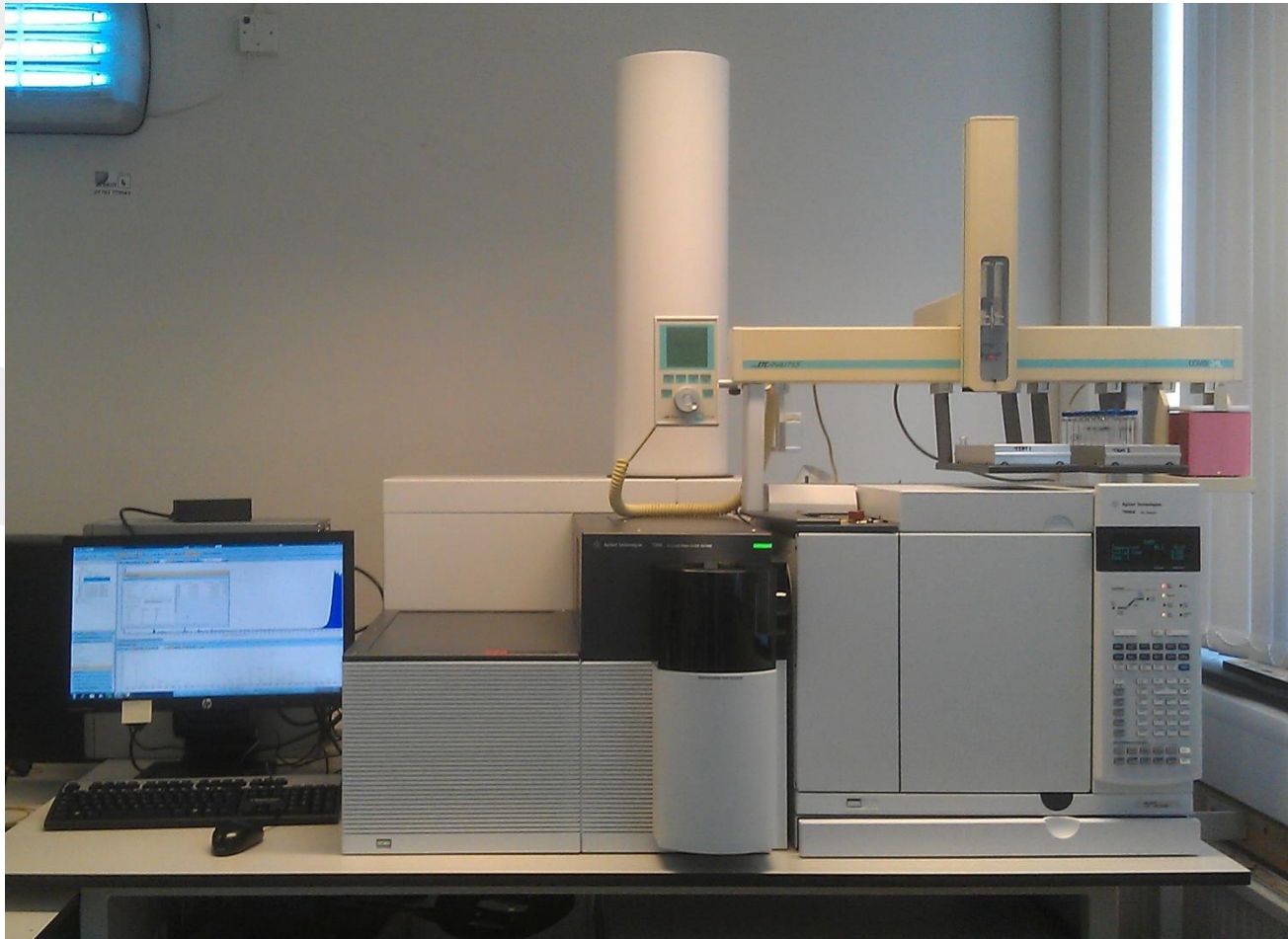


Geographical differences

- Why are the hops in each region similar to each other but different from other regions?
 - Genetically similar through breeding programmes or natural populations?
 - Consumer/brewer preferences pushing selection/breeding in one direction in a region?
 - Growing conditions/climate?
 - What are the sensory characteristics of a single hop variety grown in different regions?

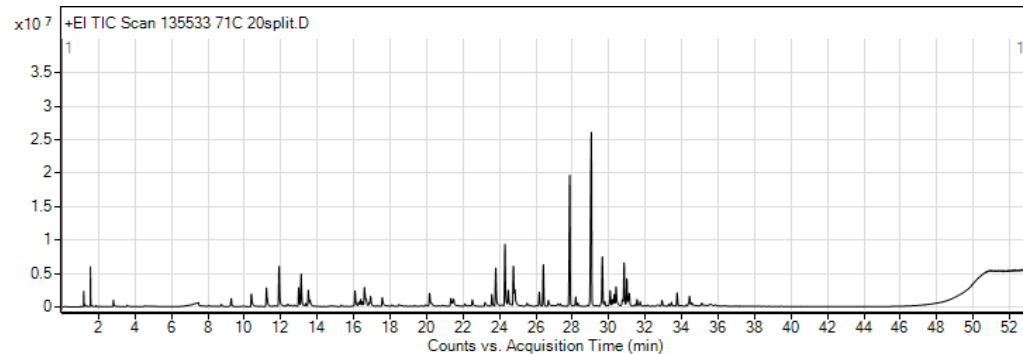
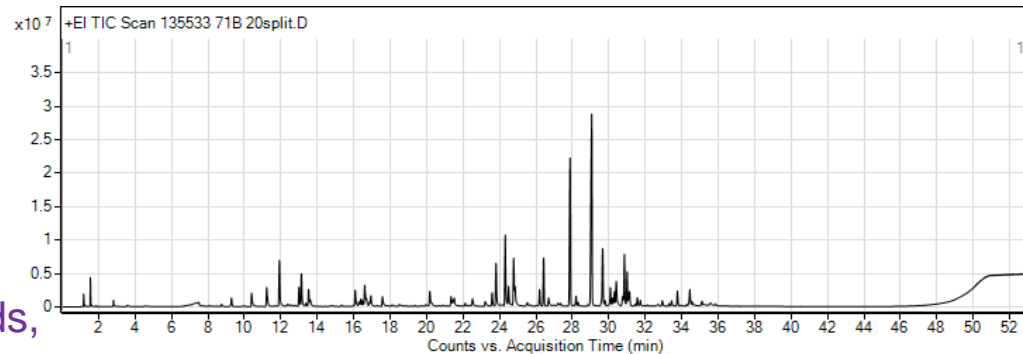
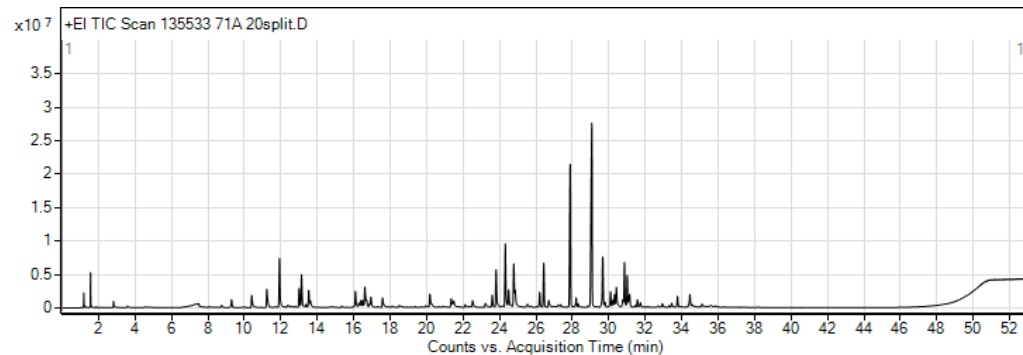
Hops analytical data

Agilent GC QToF MS



Analytical data

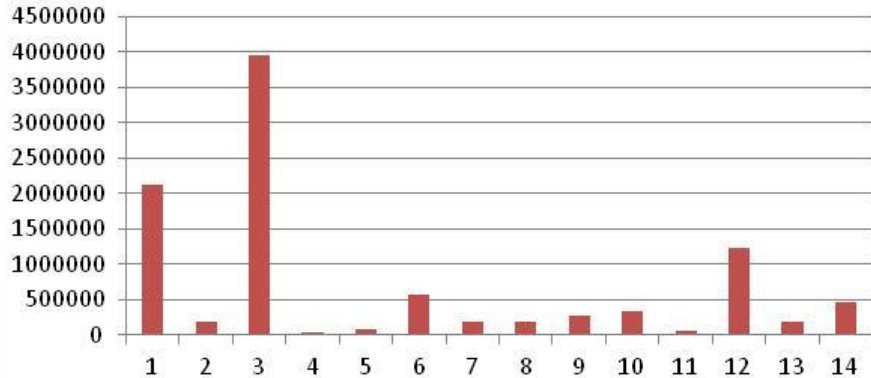
- Hops analysed by GCMS QToF (x3)
- Over 100 volatile or semi-volatile compounds identified
- The majority have known sensory properties
- Wide variation found for many compounds, as expected, in each hop variety



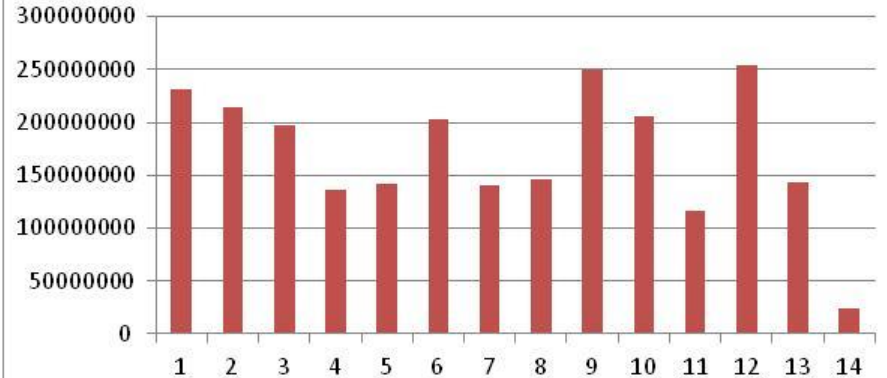
GCMS QToF: Simcoe hop pellets

Examples

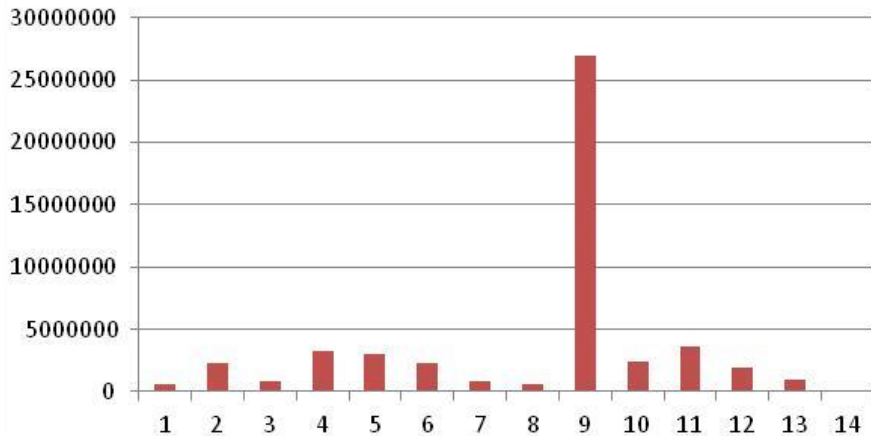
beta-myrcene (woody peppery fruity balsam)



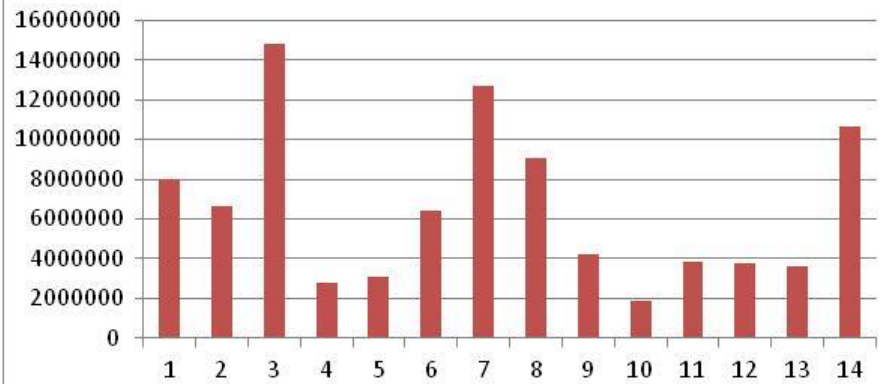
beta-pinene (dry woody resinous pine hay green)



3-carene (sweet citrus)



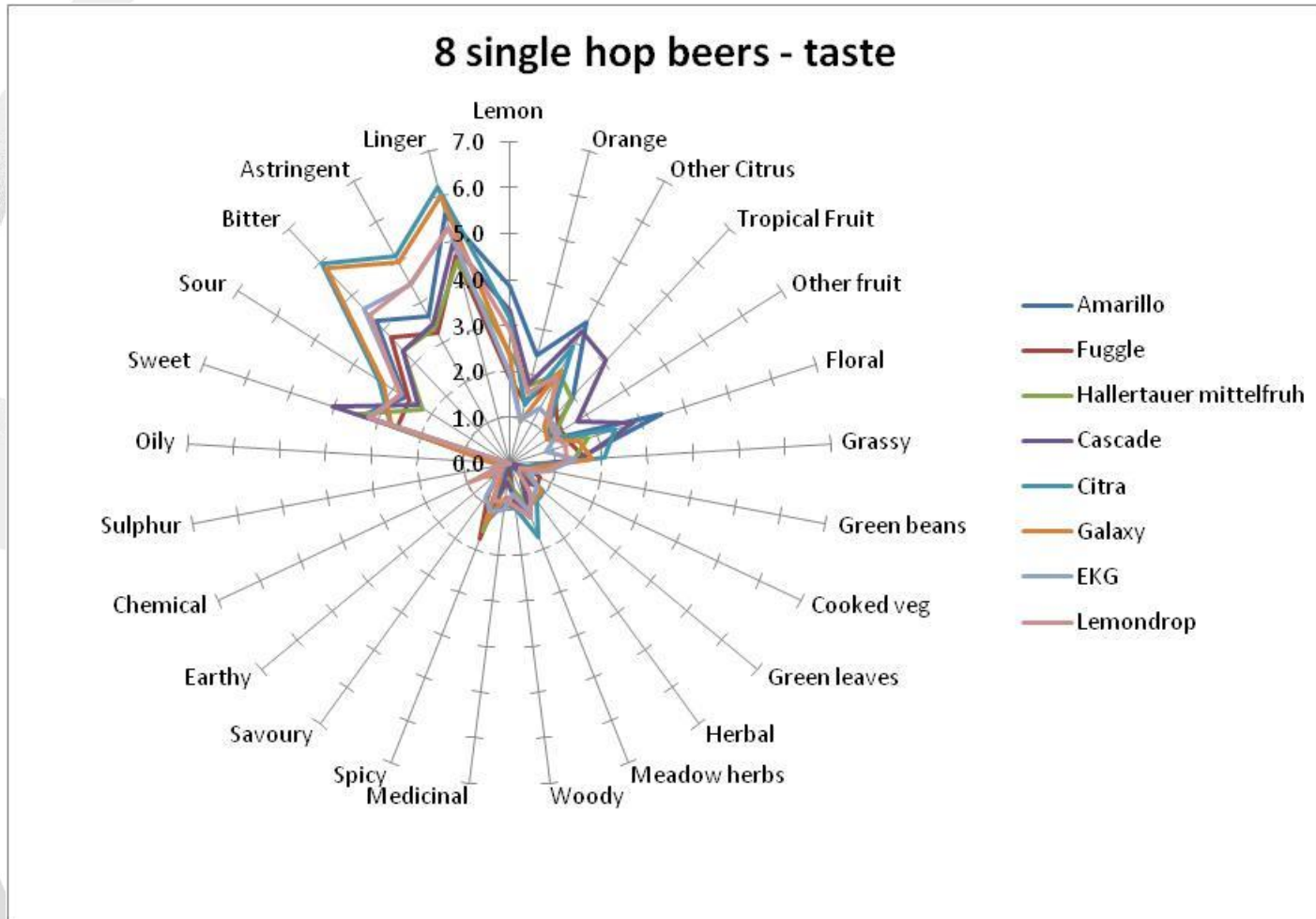
linalool (citrus floral sweet bois de rose woody green blueberry)



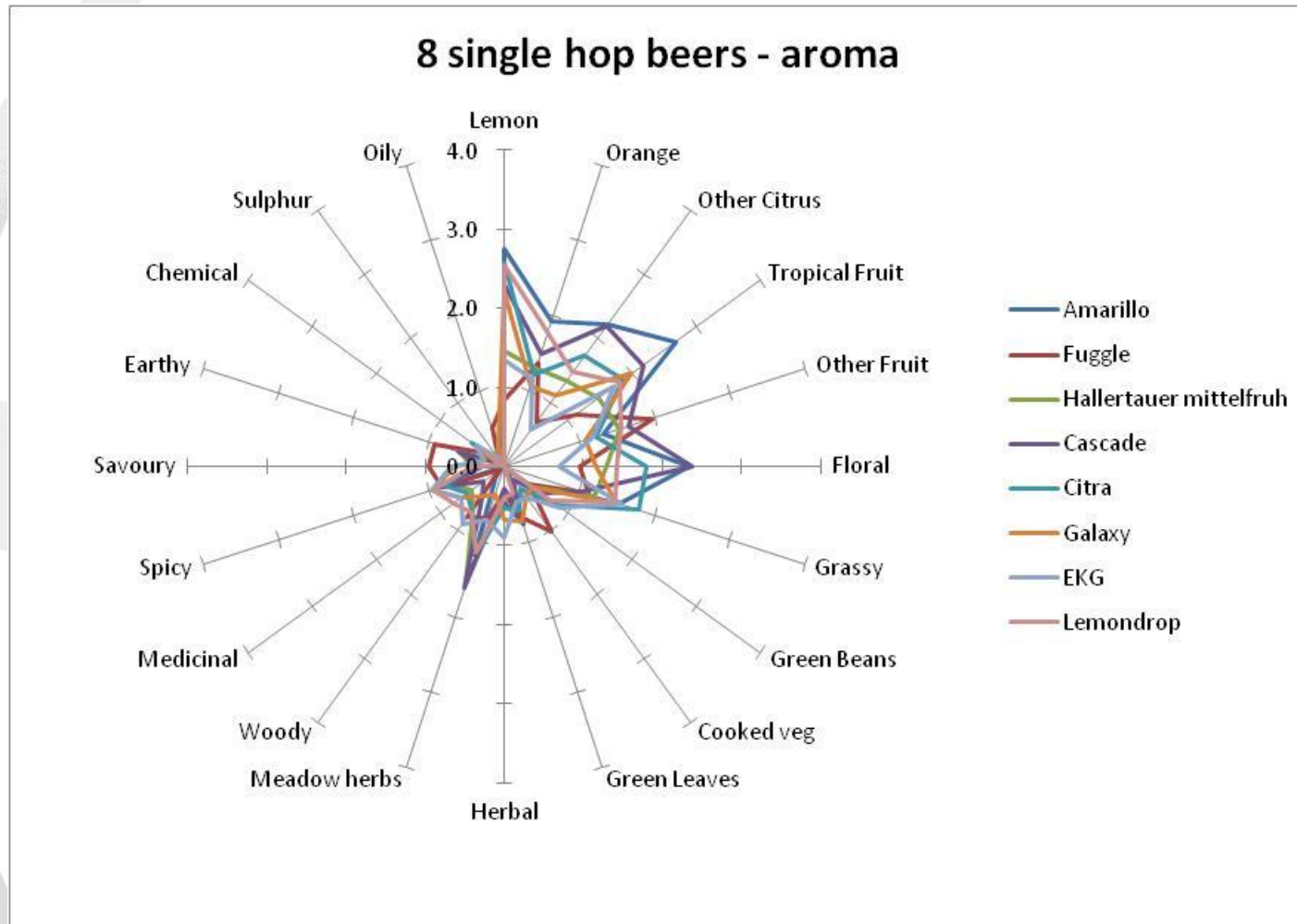
1. Amarillo, 2. Bramling Cross, 3. Citra, 4. East Kent Golding, 5. Fuggle, 6. Galaxy, 7. Hallertauer Mittelfruh, 8. Hersbrucker Spat, 9. Lemondrop, 10. Mandarina Bavaria, 11. Sovereign, 12. Cascade (US), 13. Saaz, 14. Simcoe

Single hop beer sensory data

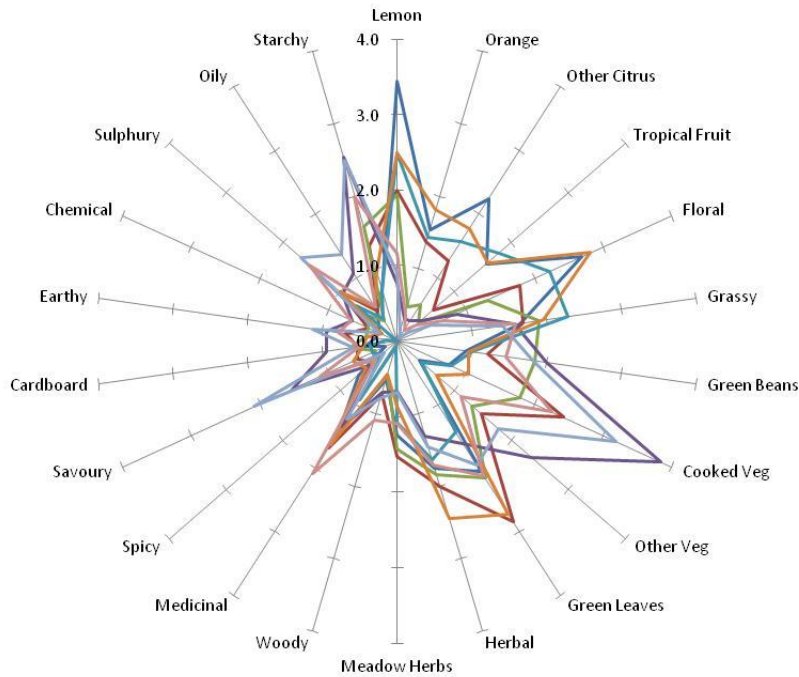
Beer sensory - taste



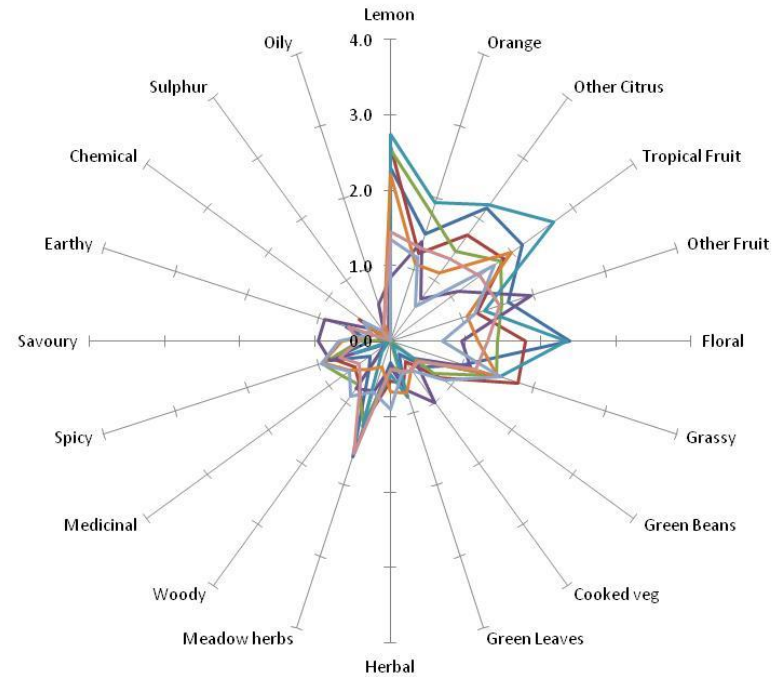
Beer sensory - aroma



Hop tea aroma vs beer aroma



Hop tea aroma



Beer aroma

- Similar in top right quadrant
- Green beans, cooked veg, green leaves, herbal medicinal <- disappeared! Why?
- Hop teas are not a good predictor of hop aroma in beer (at least not under these brewing conditions)

Single hop beer analytical data

Beer analytical data

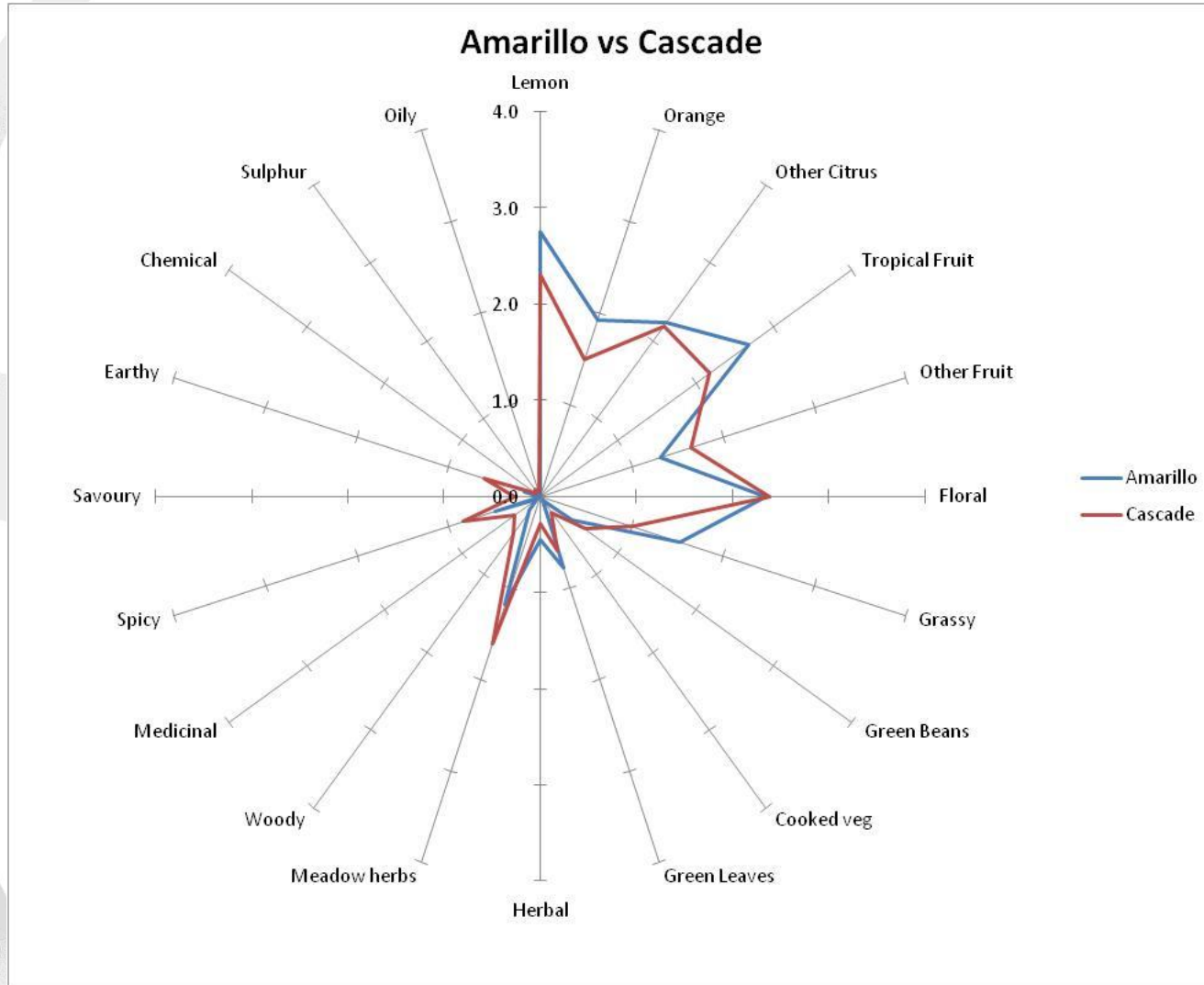
- From 120 hop compounds identified in hop teas only 9 are found in the beer namely:
 - 2-methyl-1-butanol (roasted wine onion fruity)
 - isobutyl butyrate (sweet, fruity, candy, berry, cherry, tutti frutti, over ripe and bubble gum-like)
 - beta-pinene (woody, piney, turpentine-like, minty, eucalyptus, camphoraceous, spicy peppery and nutmeg)
 - alpha-phellandrene (citrus, terpenic, slightly green, black pepper)
 - linalool (citrus, orange, floral, terpy, waxy and rose)
 - geraniol (floral, sweet, rosey, fruity and citrus)
 - humulene (woody)
 - beta-cadinene (green woody)
 - cis-calamenene (herb)

Beer analytical data

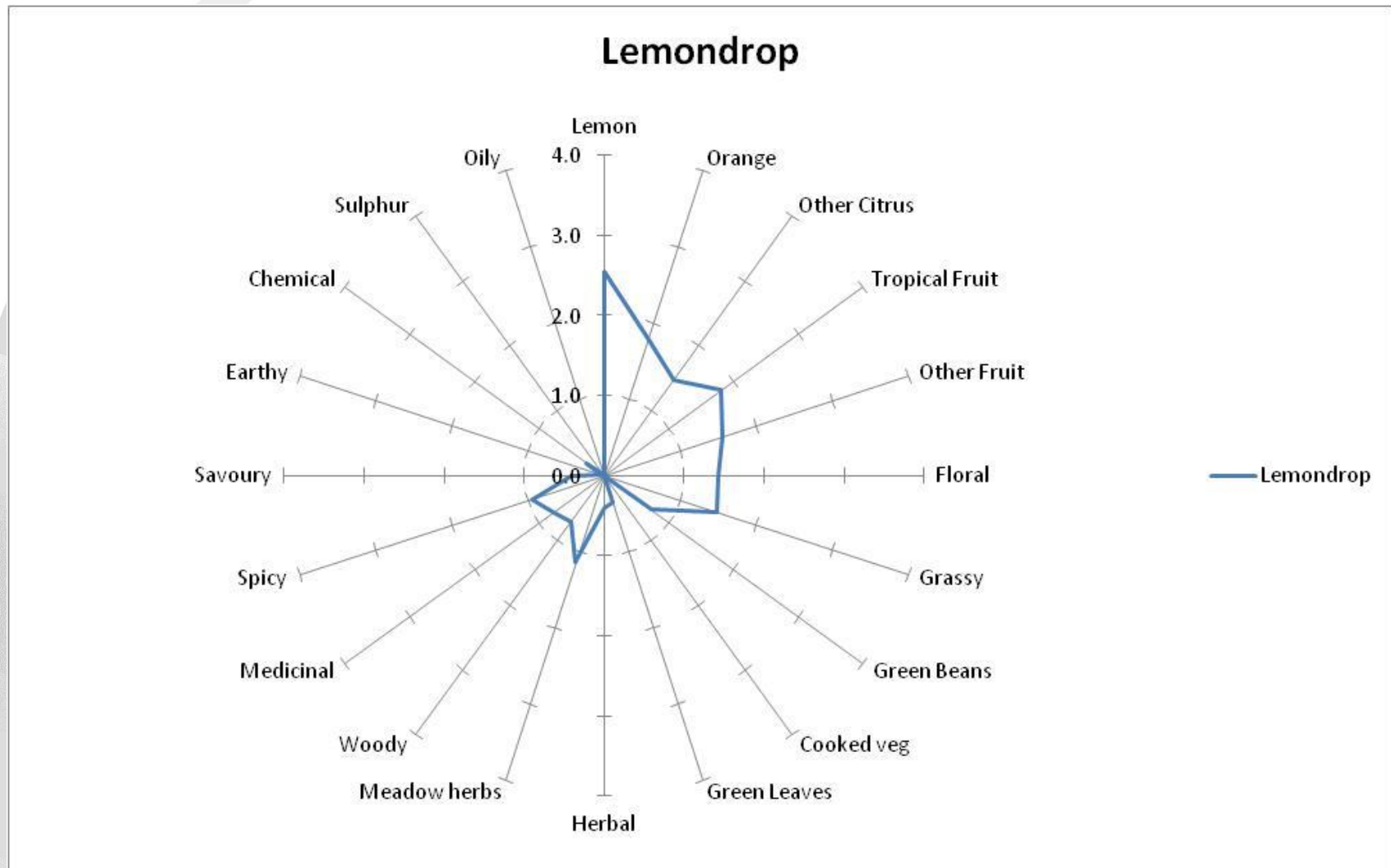
- Why so few hop cpds detected in the beer? And what happens to the sensory aroma notes?
 - Below limits of detection (analytically)
 - Masked by other compounds (analytically and sensory)
 - Chemically transformed
 - Biochemically transformed
 - Too volatile
- Some cpds are lost due to heat/CO₂ stripping etc
- Some cpds biotransformed e.g. reduction (NADH recycling?) or esterification
 - 2-undecanone (hop cpd) -> 2-undecanol (beers)
 - Decyl acetate (in beers) <- ester formed from decanol/acetic acid
- Question: late vs dry hopping – how much difference does this make?

Hop blending

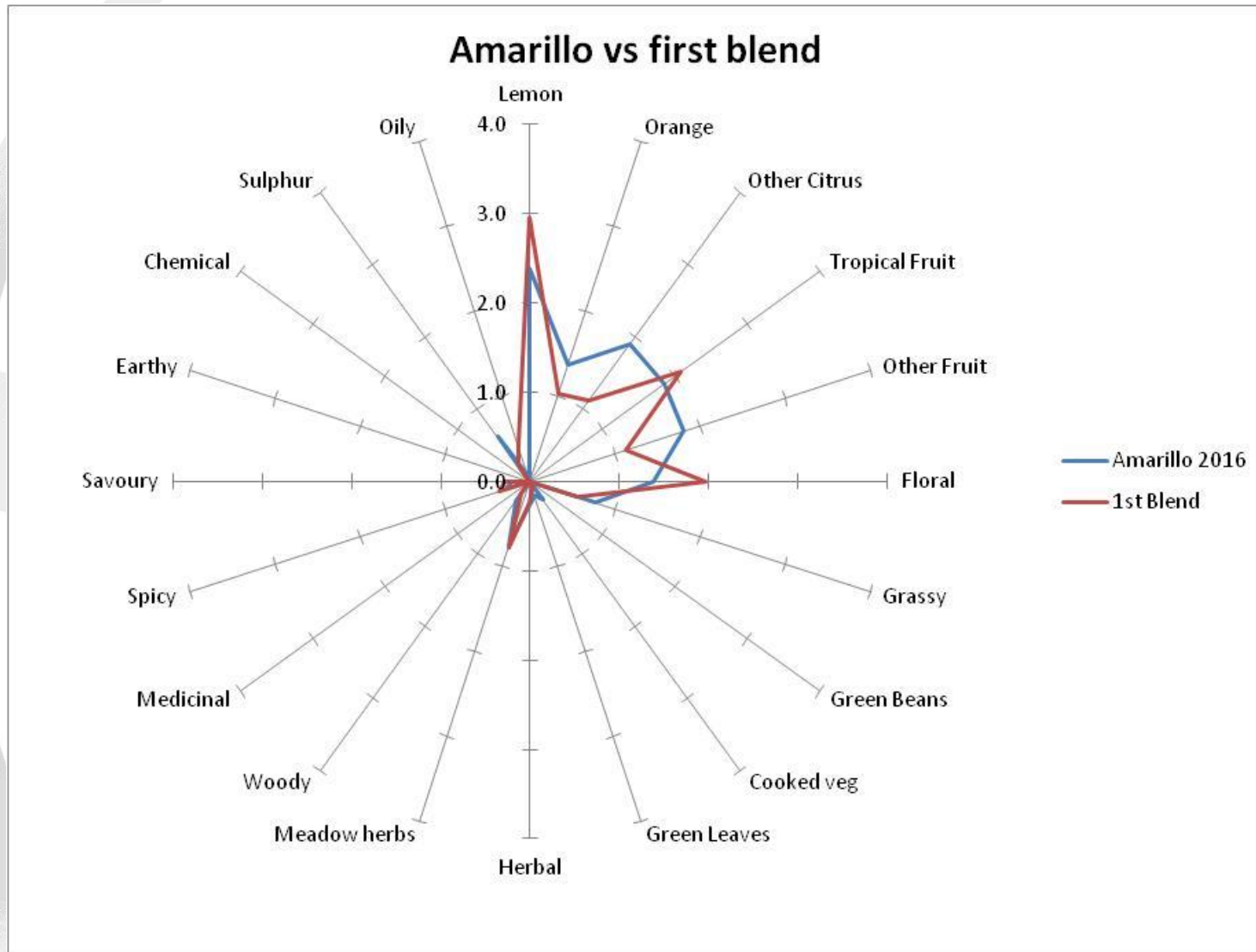
Matching Amarillo – beer data



Matching Amarillo – beer data



Matching Amarillo – beer data



Panel Tetrad Test result: no significant difference

Conclusions

- 22 fixed sensory attributes can be used to differentiate all 14 hop varieties tested
- For most varieties hop teas are a poor predictor of the sensory attributes in the final beer product
- Different hop varieties grown in the same country have very many sensory attributes in common as hop teas
- Certain aroma notes in all of the hop varieties tested are reduced, and often disappear, in the final beer especially green/herbal notes
- Blending can be assisted by sensory data but it is best done in beers not hop teas
- Amarillo can be matched in finished beer with late hop addition using Cascade and Lemondrop at a ratio of 5:1

Acknowledgements

- Ed Wray, Project brewer
- Gill Fisher, Senior sensory scientist
- Eung Lee, Project maltster
- Campden BRI members

Questions