Improving the Aroma of Plant-Based Hamburgers

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Background

- In order to provide a sustainable food source and reduce our environmental impact on the planet, we need to encourage a conversion from animal-based food products to more plant-based foods.

- Animal agriculture, cows in particular, are a significant contributor to greenhouse gas emission (methane).

- Replacing beef hamburgers with great tasting plant-based burgers would be a great start, if those products are available.

Project Objectives

- Investigate the flavor difference between a beef hamburger and some leading plant-based burgers

- Capture these findings and develop a hypothesis to understand the reason for differences in flavor

- Outline experiments that may help improve the flavor quality of these plant-based burgers.

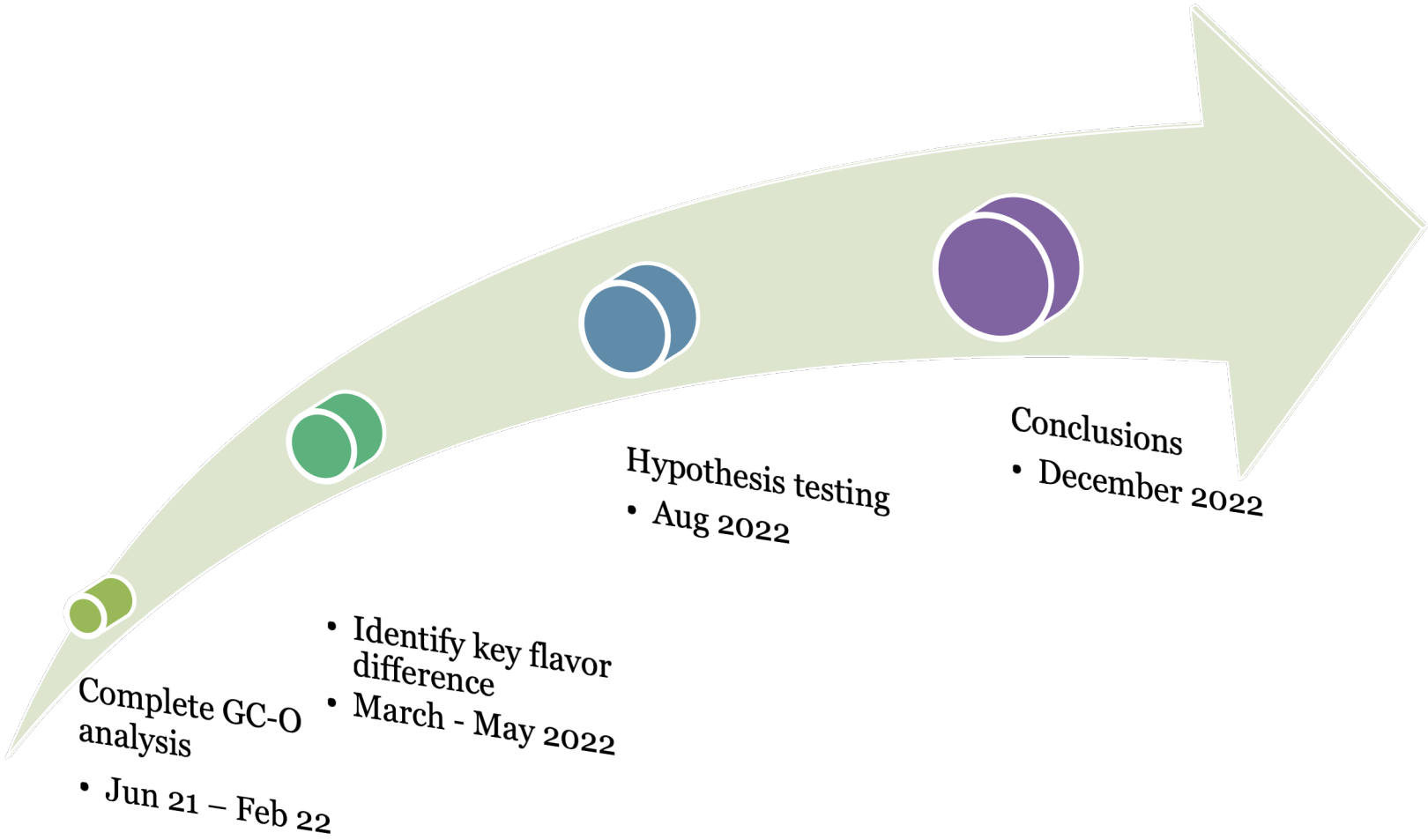
Approach

- Solid Phase Micro Extraction (SPME) used to capture the aroma compounds in the headspace above the cooked burger

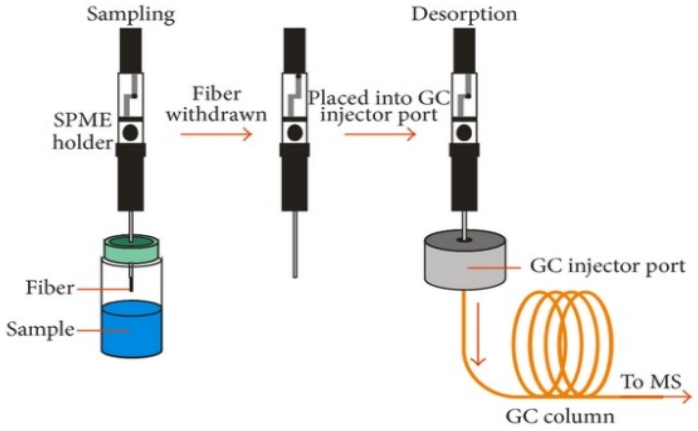
- Gas chromatography-olfactometry (GC-O) to identify key aroma compounds in beef and plant-based burgers
  - What compounds are responsible for aroma of beef burgers?
  - Are the same compounds present in the plant-based burgers?
  - What are the differences in the aroma of the products?

- Gas chromatography-mass spectrometry (GC-MS) to determine qualitative differences in these compounds

Timeline


Complete GC-O analysis
• Jun 21 – Feb 22
• Identify key flavor difference
• March - May 2022
Hypothesis testing
• Aug 2022
Conclusions
• December 2022

Solid Phase Microextraction (SPME) : Aroma Collection Procedure



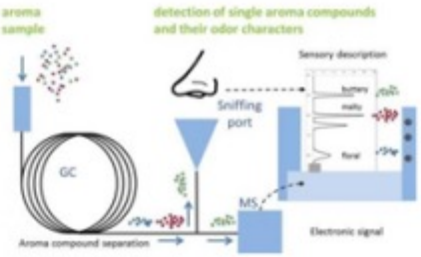
Method:

- Headspace volatiles are collected using SPME and analyzed by both GC-O and GC-MS.
- 2 grams of hamburger placed into a 22-ml SPME vial
- The samples is heated at 55°C and the volatiles are collected for 20 min using the 3-phase SPME fiber (DVB/Carb/PDMS). The fiber is then placed into the GC-inlet for analysis.
- GC column: 30 meter DB-5 (5% phenyl : 95% methyl, nonpolar column).
- Oven temp: 50°C (hold 1min); ramp at 15°C/min to 250°C hold for 5 min.
- GC-O is used to locate and identify regions in the chromatogram that are odor active
- GC-MS is used to identify the peaks and compare peak area of compounds

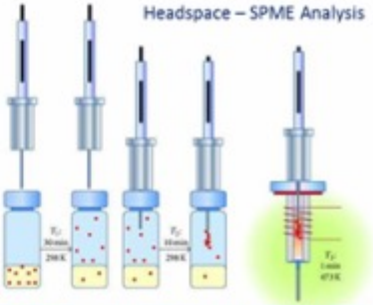
Gas Chromatography – Olfactometry (GC-O)

1.) Gas Chromatography - Olfactometry

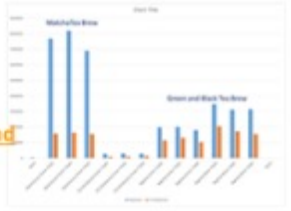
Hamburger

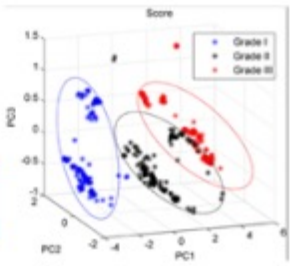


Headspace – SPME Analysis



Data Processing: Charts, Multivariant Analysis: PCA and HCA

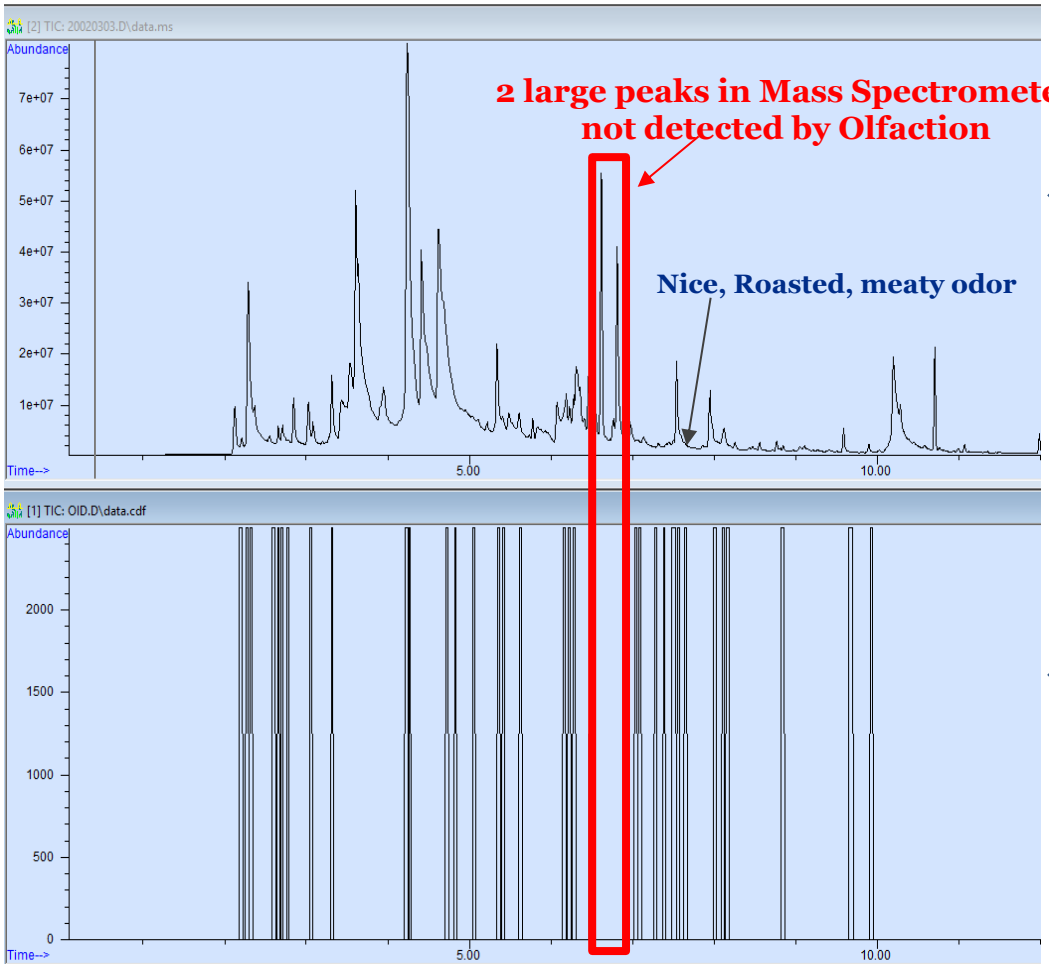




2.) SPME-GC-MS Comparison

"Good Reproducible and Qualitative comparison but not quantitative: Good for giving direction"

GC-O of a Beef Burger showing 34 Odor Active Peaks



Beef burger analyzed by Solid Phase MicroExtraction (SPME-GC-MS): 2g extracted for 30 min at 55ºC

Mass Spectrometer Detector
~100+ compounds detected

Olfaction Detector
34 odorants detected

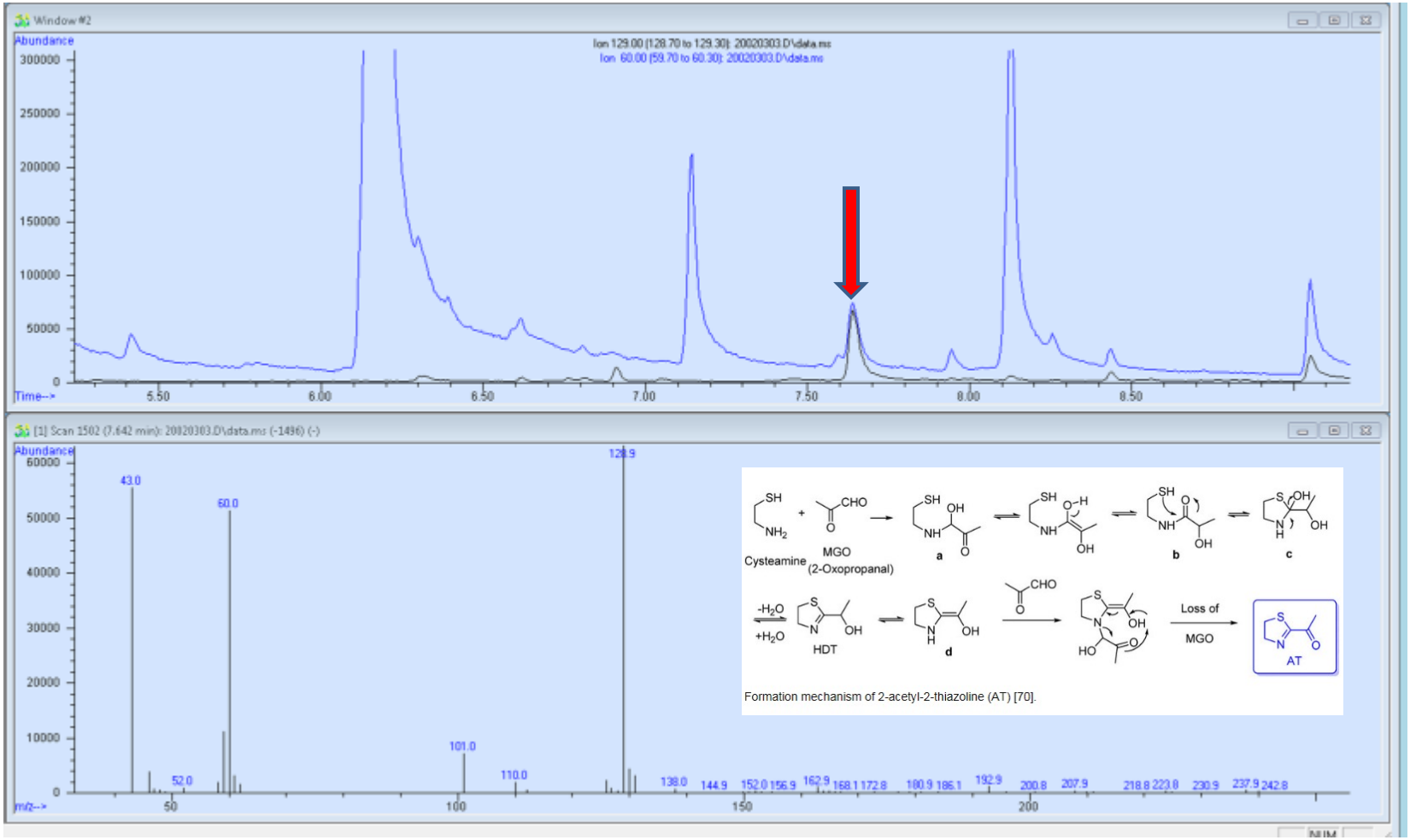
- Description: savory, grilled, sweet
- Intensity: low, medium, strong

Benefits of GC-O:

- ***Focuses on odor active compounds***
- ***Strong correlation with Sensory Perception***

Identification of a Nice Roasted, Meaty Odor Compound

Roasted, nice popcorn odorant eluting at 7.65 min is 2-Acetyl-2-thiazoline
Solid Phase MicroExtraction (SPME-GC-MS) analysis of 2g at 55C for 30 min



Formation mechanism of 2-acetyl-2-thiazoline (AT) [70].

Odor Compounds Identified in Beef Burger

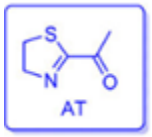
Peak Start	Peak End	Intensity	Comment	Possible Compound
02.18	02.22	1	Decay L	Methanethiol
02.26	02.29	1	Sulfury M	Dimethyl Sulfide
02.31	02.35	1	Sulfur stinky note M	
02.58	02.62	1	malty buttery L	2-methyl propanal
02.65	02.68	1	sulfur note L	
02.69	02.71	1	Buttery S	diacetyl
02.76	02.79	1	stinky note L	
03.04	03.07	1	Malty M	3-methyl butanal
03.30	03.33	1	buttery L	acetoin
04.21	04.25	1	malodor acid stinky M	isovaleric acid
04.26	04.28	1	Green M	hexanal
04.70	04.74	1	Sweaty M	
04.82	04.84	1	sweaty M	
05.04	05.07	1	roasted nice m	2-Methyl-3-furanthiol
05.34	05.38	1	Green yucky M+	heptanal/cis-4-heptenal
05.40	05.43	1	methional S	methional
05.61	05.64	1	roasted note nice M	2-acetyl-1-pyrroline
06.15	06.19	1	yucky earthy L	
06.20	06.24	1	Mushroom dirt earthy M	1-octen-3-one
06.26	06.31	1	another stinky M	dimethyl trisulfide
06.48	06.51	1	orange Octanal M+	octanal
07.02	07.06	1	phenylacetaldehyde L+	phenylacetaldehyde
07.08	07.11	1	carmelized sugar note M+	furaneol (4-hydroxy-2,5-dimethyl-3(2H)furanone)
07.27	07.30	1	p-cresol L	p-cresol
				2-ethyl-3,5-dimethyl pyrazine??? Need
07.38	07.41	1	Earthy M+	confirmation
07.48	07.53	1	fatty aldehyde waxy plastic M	nonanal
07.55	07.58	1	Still same M	nonanal
07.63	07.67	1	Popcorn roasted nice M+	2-acetyl-2-thiazoline
08.00	08.03	1	Plastic vinyl M	2-nonenal
08.09	08.13	1	Plastic vinyl M	2-nonenal
08.14	08.19	1	Fatty aldehyde M	2,4-nonadienal
08.82	08.87	1	maybe a carmelized sugar note L_	
09.65	09.70	1	fatty aldehyde fried M	2,4-decadienal?
09.91	09.95	1	just missed another possible fried fatty note L	2,4-decadienal?

Buttery

Roasted, meaty

Lipid aldehydes

Interesting, nice roasted and meaty odor which is absent in the plant-based burgers!



2-acetyl-2-thiazoline

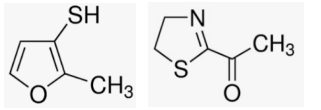
Why is it absent in the plant-based burgers? How is it formed?

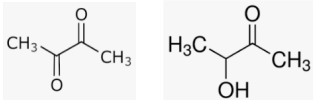
Odor Active Compounds of Meat Hamburger

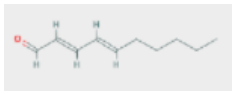
Meat based Hamburger is high in meaty, grilled, fatty, sweet savory notes.

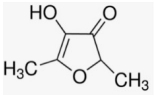
Summary of our work to date:

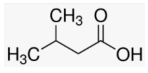
Odor drivers appear to be sulfur compounds, lipid aldehydes, buttery and sweet roasted notes

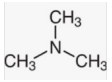












Sulfury, Meaty:

2-Methyl-3-furanthiol Methional
Methanethiol Dimethyl trisulfide
2-acetyl-2-thiazoline

Roasted, toasted:

2-ethyl-3,5-dimethylpyrazine 2-acetyl-1-pyrolline

Buttery, sweet, and malty

Diacetyl Acetoin 2-methylpropanal
3-methyl butanal 2-methylbutanal

Fatty Notes

Hexanal Decanal 2,4-decadienal
Octanal 2-Nonenal heptanal
Nonanal 2,4-Nonadienal cis-4-heptenal

Carmelized sugar, sweet:

4-Hydroxy-2,5-Dimethyl-3(2H) furanone
Maltol norfuraneol

Sweaty, acidic, animalic:

Isovaleric acid p-cresol trimethylamine
Indole skatole

Current Status and Next Steps

- Significant differences in odor compounds have been identified between beef and plant-based burgers.

- My research is focusing on one specific compound, 2-acetyl-2-thiazoline (2-AT), which is present in beef burgers but not plant-based.

- Next phase of work will be to understanding the formation mechanism of 2-AT formation in beef burgers

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