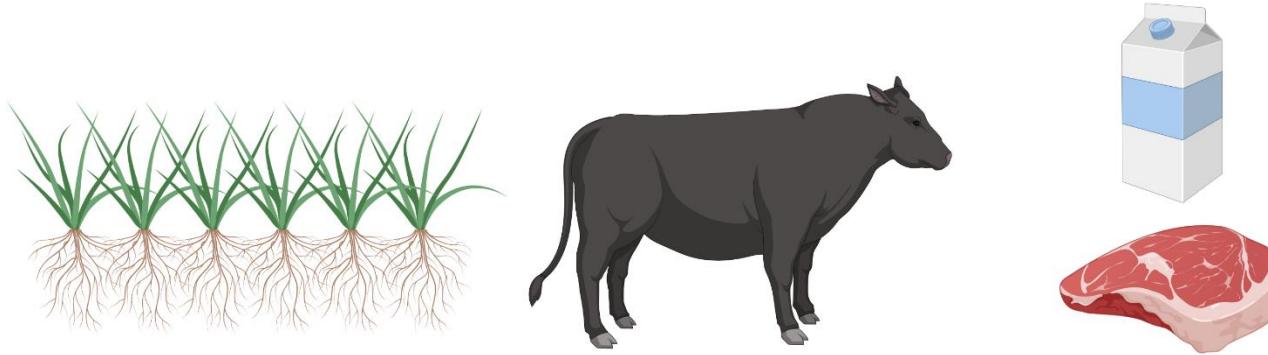


Beyond the Label: Understanding Nutrient Density And the Science Behind It



Stephan van Vliet, PhD
Director, Center For Human Nutrition Studies
College of Agriculture and Applied Sciences
Utah State University

Email: stephan.vanvliet@usu.edu

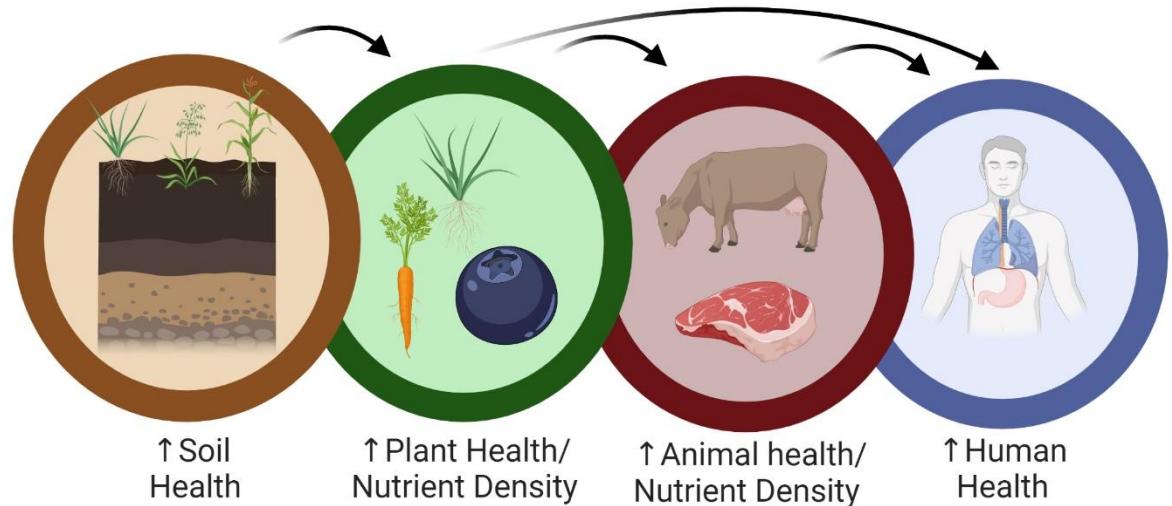


@vanvlietphd Stephan van Vliet

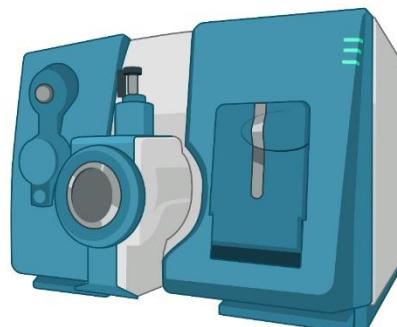


My lab's research interest

- Work performed at the nexus of agriculture-animal-human health.
- Two major interests:
 - 1) Linking soil, plant, and animal health to food nutrient density.
 - 2) Feeding people foods from different production systems in randomized controlled trials to determine potential effects on human health.



The *goal* of my research program is to systematically define linkages between sustainable agriculture systems, the nutrient quality of foods, and human health.

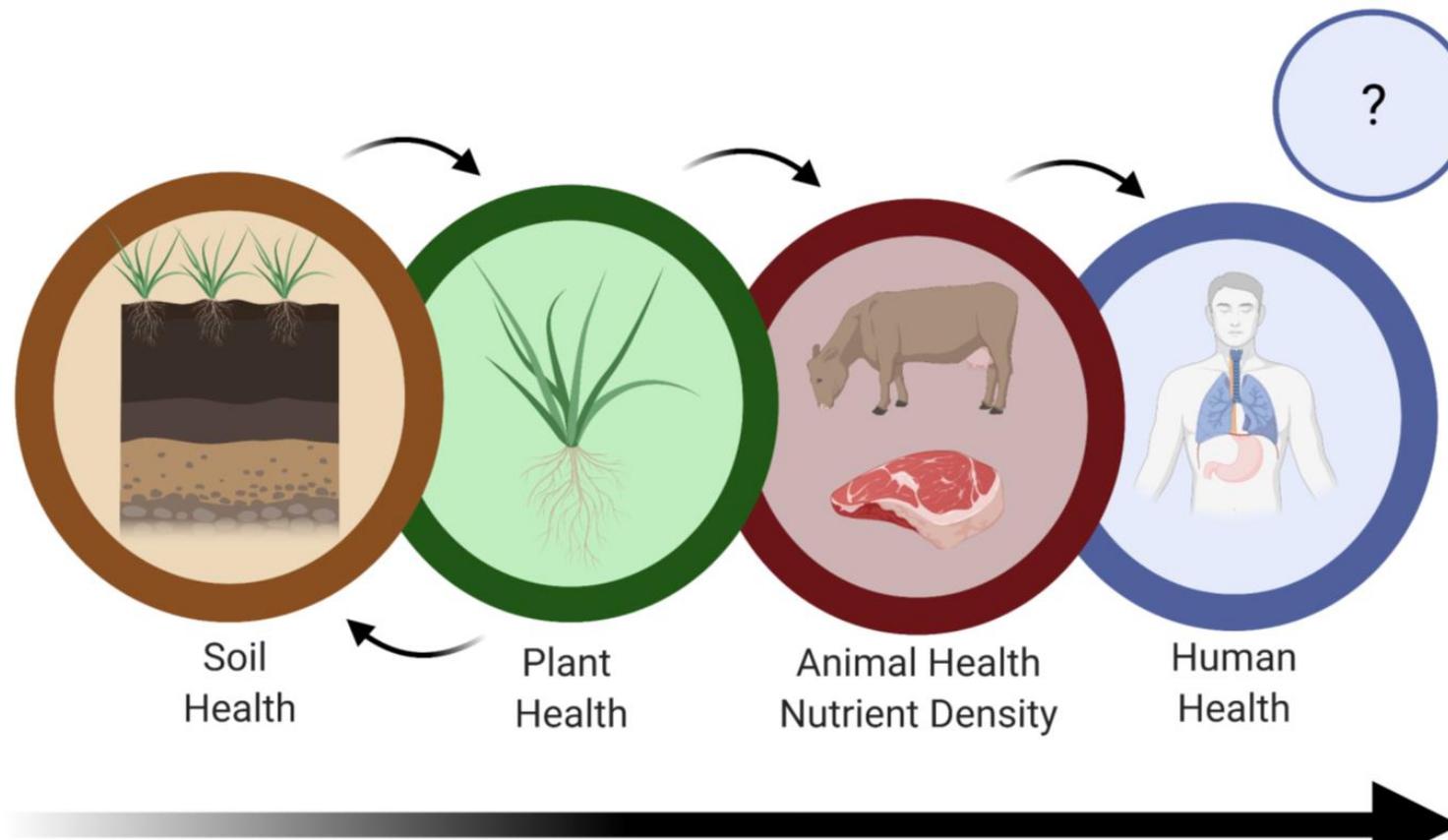


Metabolomics. Profiling of biological samples (including feed/food) to gain insight into 800+ compounds across 15+ nutrient/metabolite classes



Clinical Trials. Test health effects of dietary patterns, rich in these foods, on biomarkers of human metabolic health

Understanding Relationships Amongst Soil, Plant, Animal, and Human health



Nutrient transfer across systems:

**Healthy soils, healthy plants,
healthy animals, healthy humans?**

A half truth to the saying you are what you eat!

Article

A reference map of potential determinants for the human serum metabolome

<https://doi.org/10.1038/s41586-020-2896-2>

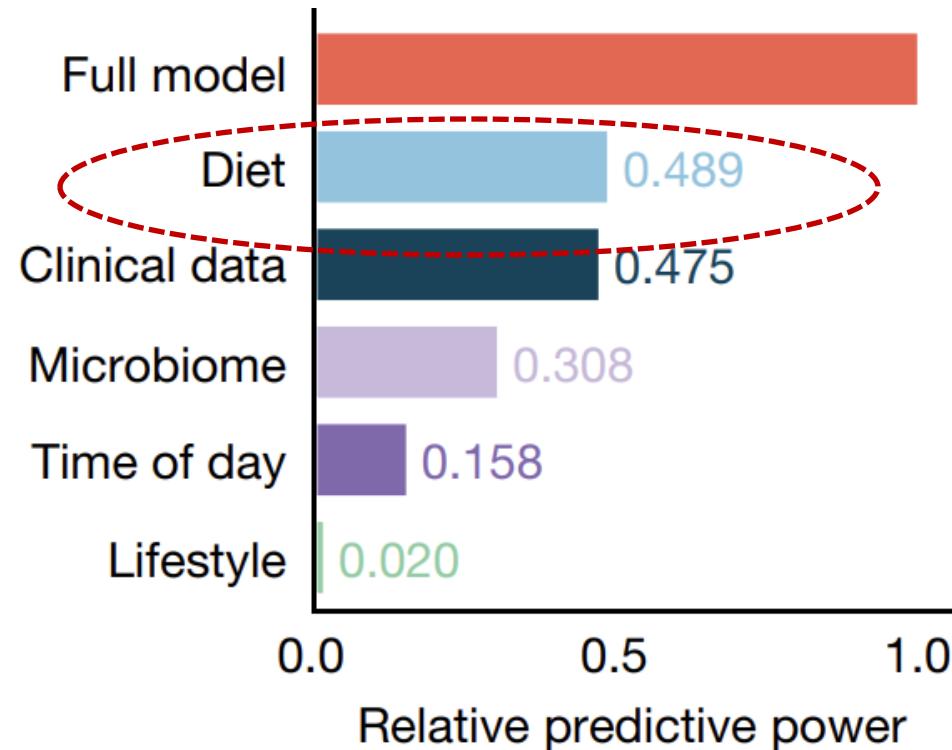
Received: 23 January 2019

Accepted: 29 September 2020

Noam Bar^{1,2,81}, Tal Korem^{1,2,3,4,5,81}, Omer Weissbrod^{1,2,6}, David Zeevi^{1,2,7}, Daphna Rothschild^{1,2}, Sigal Levitan^{1,2}, Noa Kosower^{1,2}, Maya Lotan-Pompan^{1,2}, Adina Weinberger^{1,2}, Caroline I. Le Roy⁸, Cristina Menni⁸, Alessia Visconti⁸, Mario Falchi⁸, Tim D. Spector⁸, The IMI DIRECT consortium*, Jerzy Adamski^{9,10,11}, Paul W. Franks^{12,13}, Oluf Pedersen¹⁴ & Eran Segal^{1,2,82}



You are what you eat.... Sort of



About 50% of what circulates in our body is determined by what we eat

A half truth to the saying, you are what you eat!

Article

A reference map of potential determinants for the human serum metabolome

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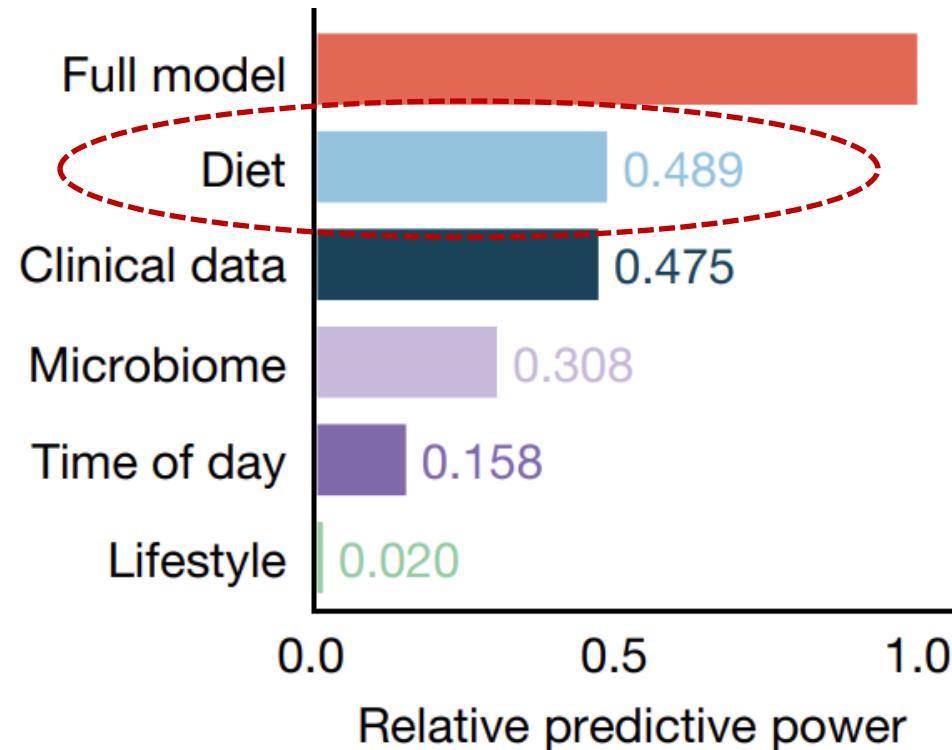
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I am what I ate?



About 50% of what circulates in the human body is determined by what we eat

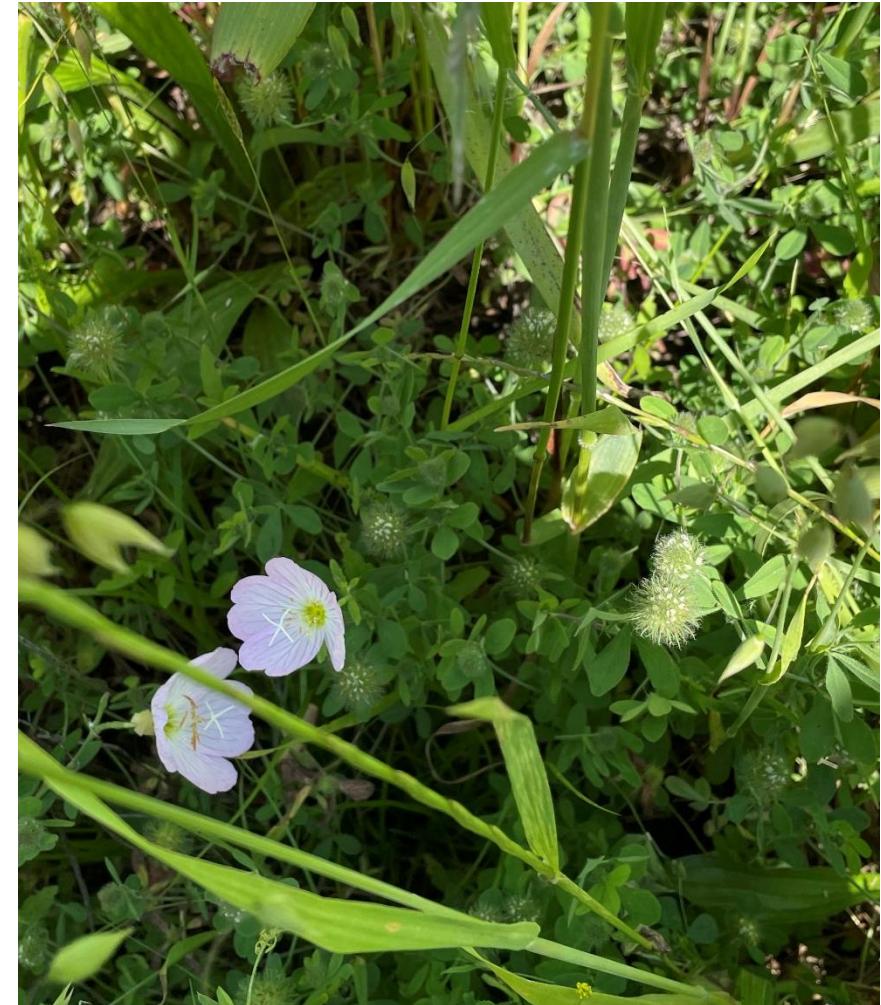
On farm sample collection....



Sample collection.... Soil samples



Corn field (used for
livestock feed)



Biodiverse pasture
~ 1 mile apart

Sample collection.... Plant samples

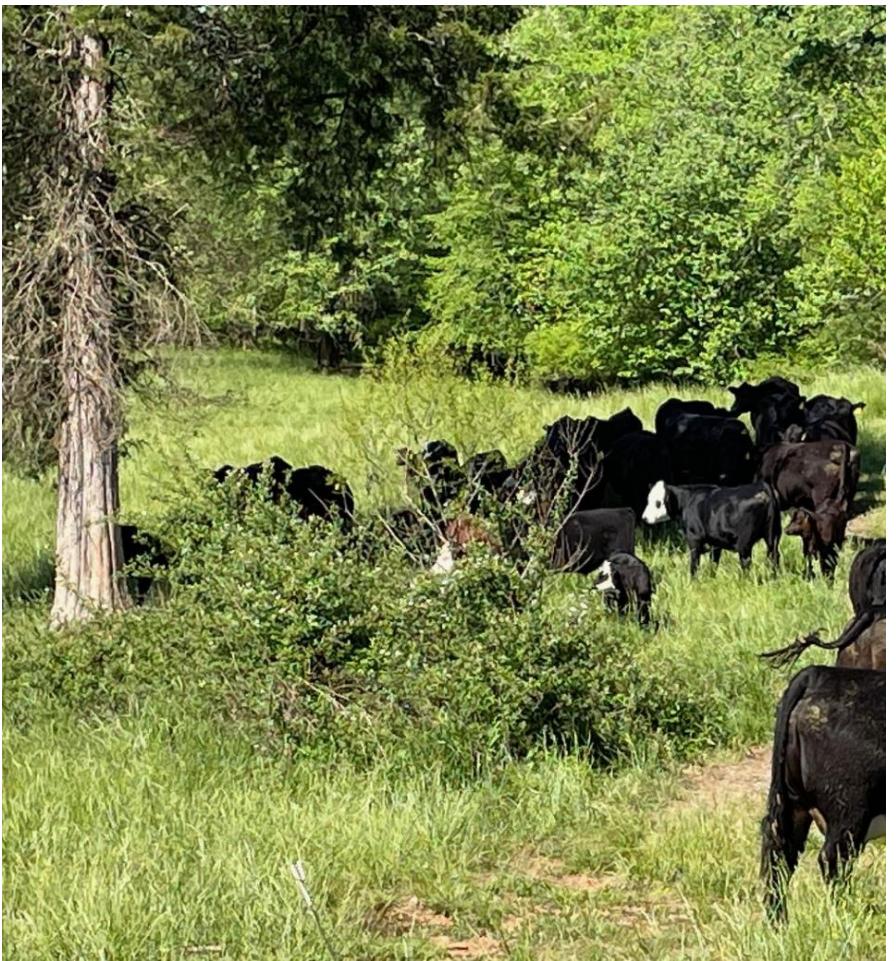
TMR Sample
(Feedlot-finished)



Pasture Sample
(Grass-fed/finished)



Meat samples

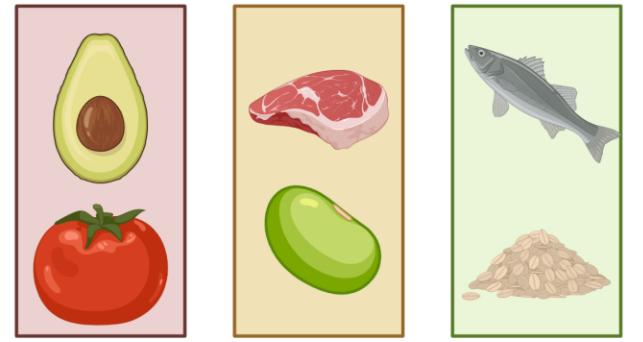


A need to move beyond “protein” and “fat” and consider the food matrix



Nutrition Facts	
Serving Size 4 oz (112g) Servings Per Container varied	
Amount Per Serving	
Calories 140	Calories from Fat 40
% Daily Value*	
Total Fat 4.5g	7%
Saturated Fat 2g	10%
Cholesterol 55mg	19%
Sodium 75mg	3%
Total Carbohydrate 0g	0%
Protein 24g	
Iron 15% • Riboflavin 10%	
Vitamin B6 20%	• Vitamin B12 40%
Zinc 40%	
Not a significant source of dietary fiber, sugars, vitamin A, vitamin C, and calcium.	
*Percent Daily Values are based on a 2,000 calorie diet.	

Food Metabolome



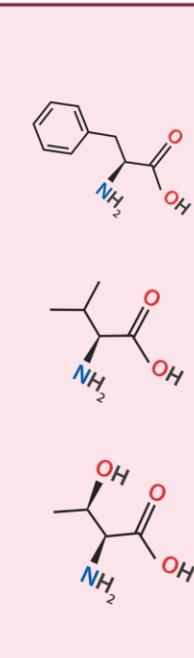
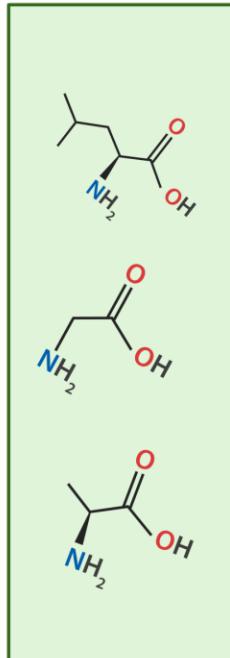
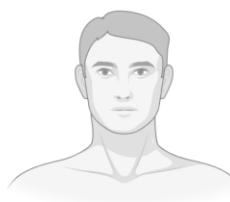
Only **13 nutrients** appear on food labels.....

USDA Food Composition Databases track 150 components in food and form the basis of our "nutritional understanding" and dietary guidelines/policies.



Food sources contain **>30,000 compounds** capable of impacting human health and metabolism

Human Metabolome



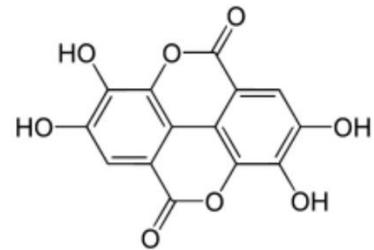
Nutrigenome



A	T
T	A
G	C
C	G
G	C
A	T
C	G
T	A

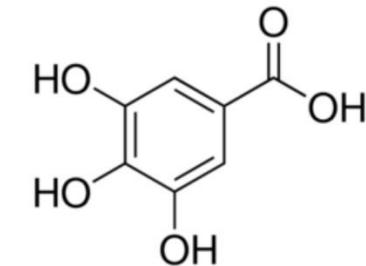
“Protein” is important but there is a need to look at nutrient density from a broader lens taking into the 1000s of compounds in foods

Nutrients in meat (>1,000 compounds)



Tannins
Anti-inflammatory, anti-oxidant, cancer-protective, and neuroprotective (e.g., Alzheimer's)

Phytochemicals
Anti-oxidant, anti-diabetes, cancer protective, improved brain health

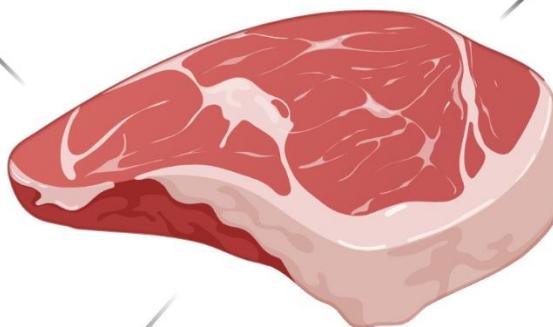


Peptides
Anti-oxidant, cancer protective, neuroprotective, cardiovascular protective, liver protective

Vitamin B metabolites
Essential nutrient
Promotes a healthy nervous system, digestive system, and skin

Energy Metabolites
Anti-inflammatory, anti-oxidant, brain protective, and cardiovascular protective

Choline metabolites
Essential vitamin that can help with healthy liver function, healthy brain development, muscle movement, and the nervous system



Nutrient Density Testing

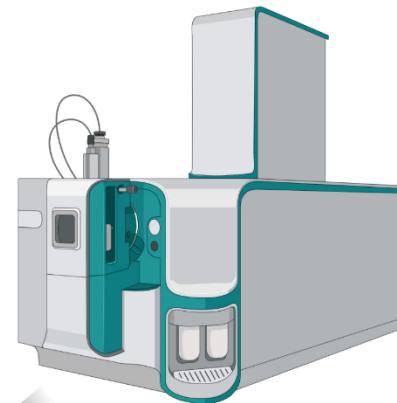
a Sample collection



b Sample processing



c Untargeted analysis

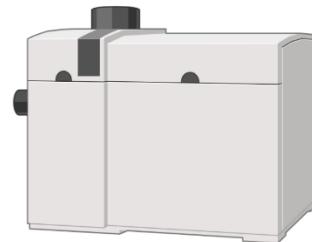


d Targeted extractions and analysis using AOAC methods

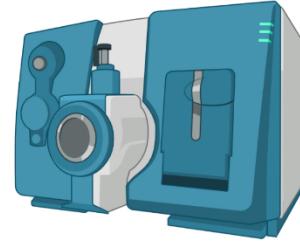
1. Fatty acids by GC-FID



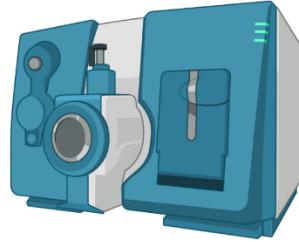
2. Minerals/heavy metals by ICP-MS



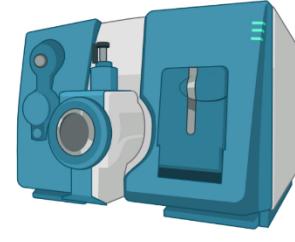
3. Phytochemicals by LC/MS-MS



4. B-vitamins by LC/MS-MS



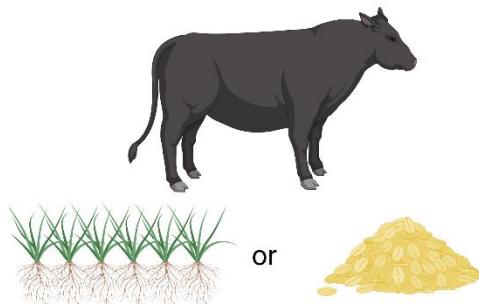
5. Fat Soluble Vitamins by LC/MS-MS



Grass-fed isn't grain-fed and grain-fed isn't grass-fed

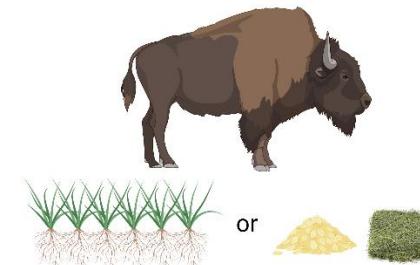
Grass-fed vs grain-fed beef

Total Biochemicals Identified	825
Total Biochemicals $p < 0.05$	462 (56%)
↑Grass	286
↑Grain	176
Total Biochemicals $0.05 < p < 0.10$	26 (4%)
↑Grass	18
↑Grain	8



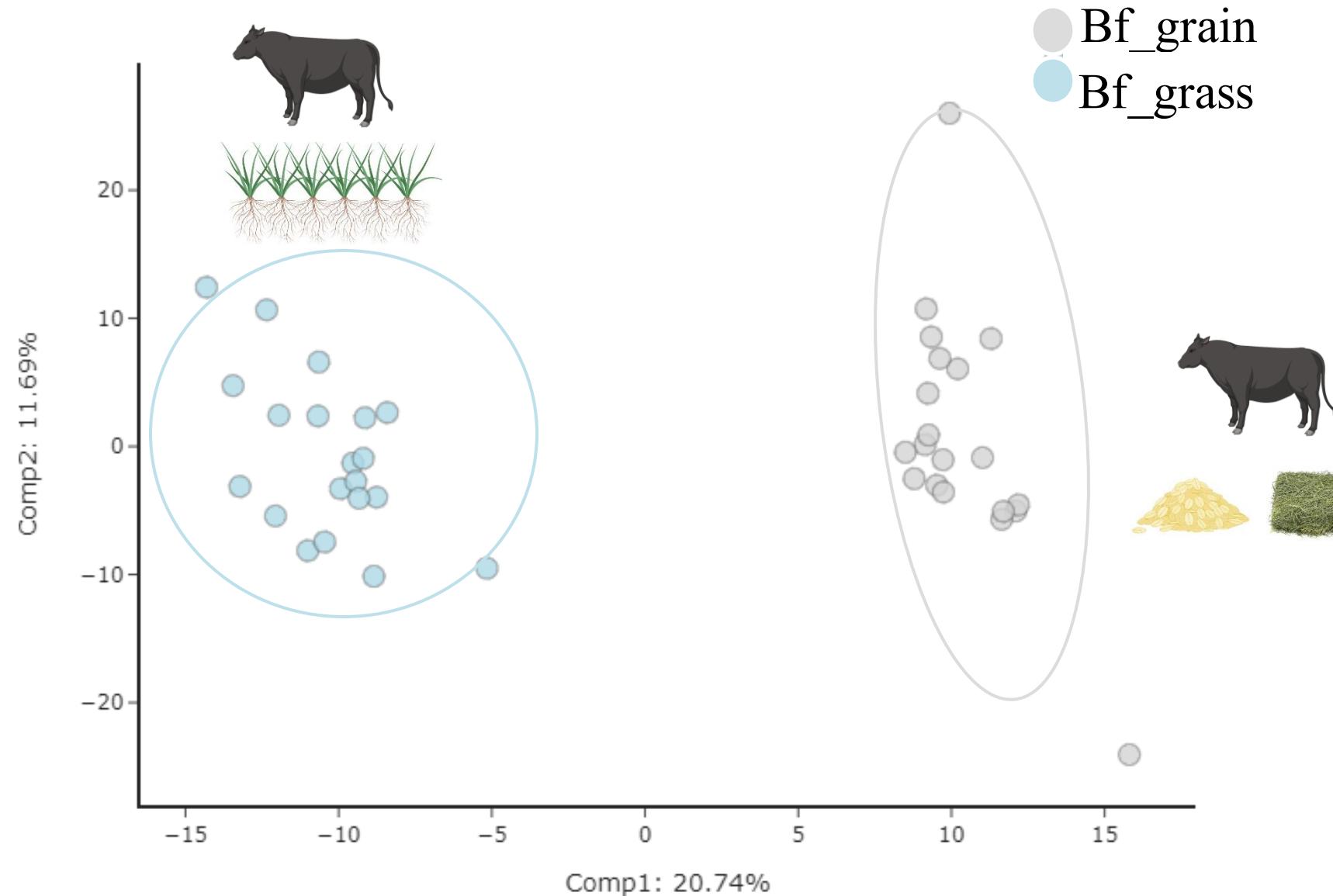
Grass-fed vs grain-fed bison

Total Biochemicals Identified	538
Total Biochemicals $p < 0.05$	278 (52%)
↑Grass	115
↑Grain	163
Total Biochemicals $0.05 < p < 0.10$	42 (8%)
↑Grass	18
↑Grain	24



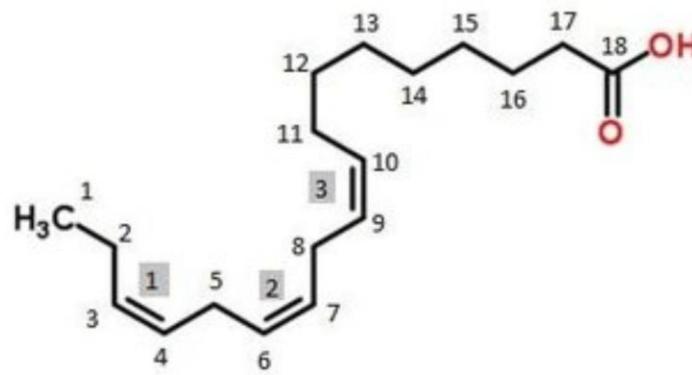
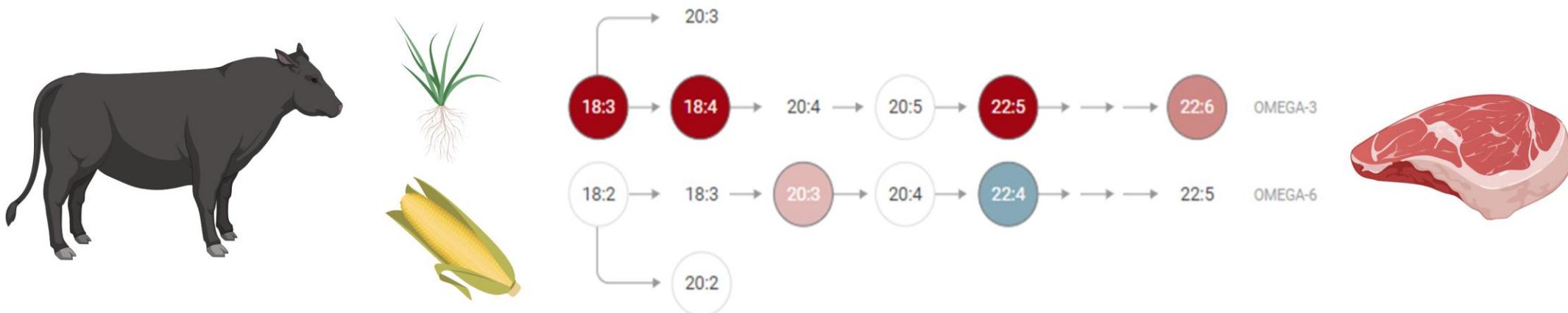
50% difference in metabolites/nutrients is larger than previously appreciated...
Nutritional differences go far beyond just omega-3 fats! But let's start with those.

High level overview of the data set indicates clear differences

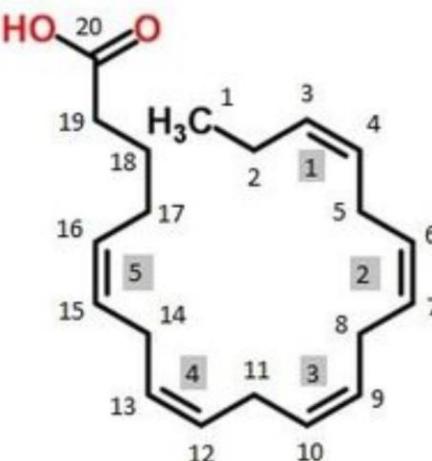


When compared between grass-fed and grain-fed samples, the distinction implies we are looking at very much different phenotypes (or food types).

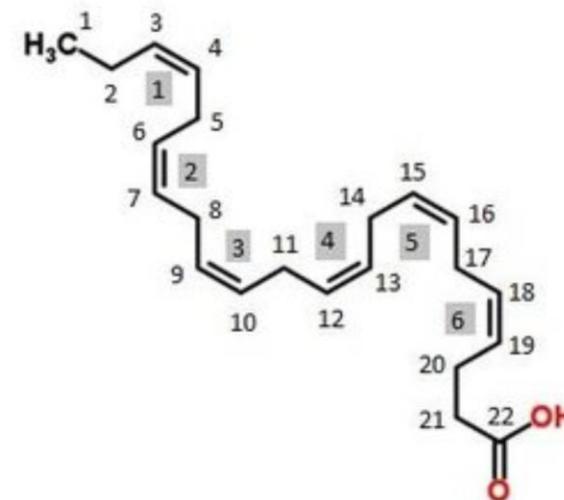
Fatty acid data



Alpha-linolenic acid (ALA)
18:3n-3

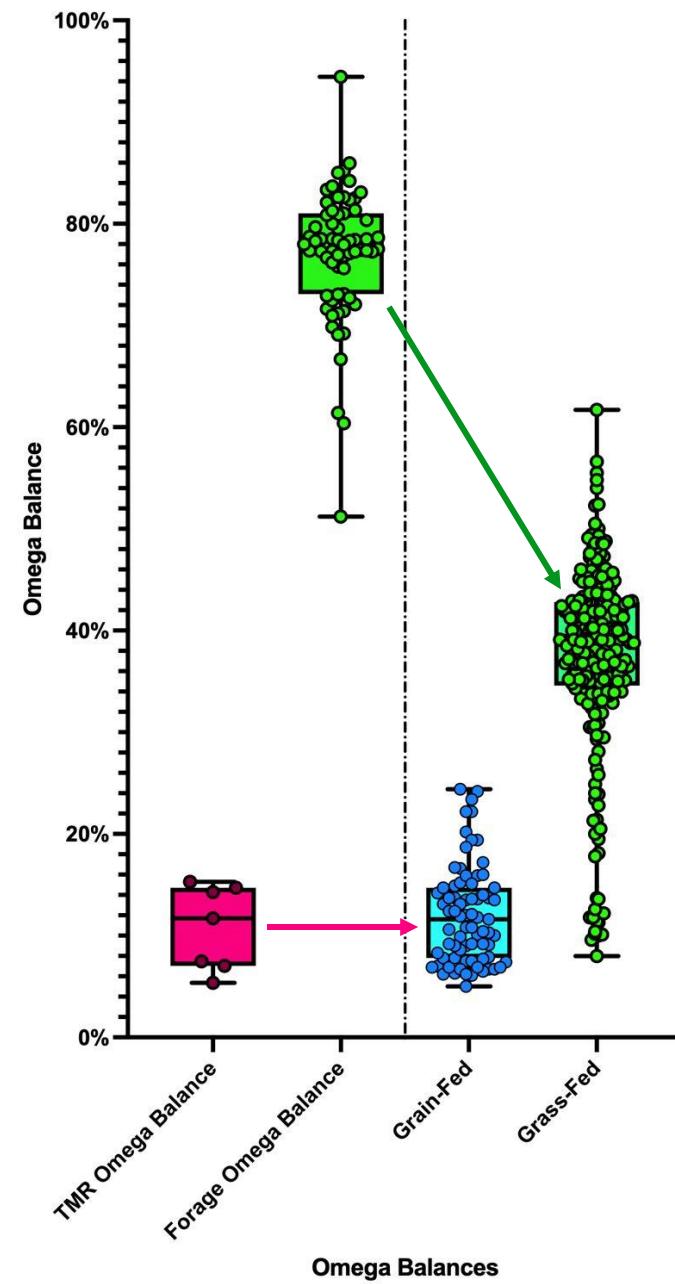


Eicosapentaenoic acid (EPA)
20:5n-3

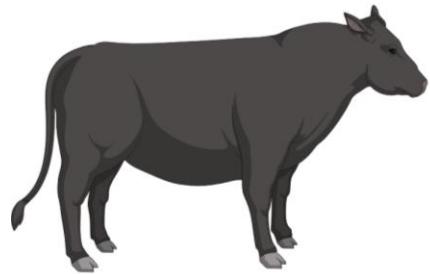


Docosahexaenoic acid (DHA)
22:6n-3

Omega Balance (OB)
in Feed and Meat by Group

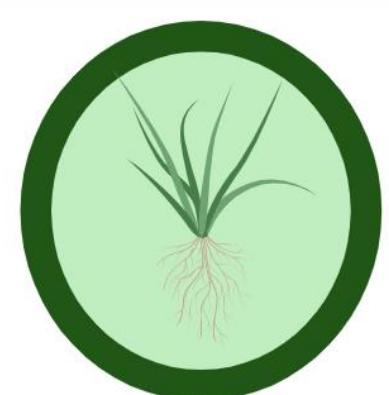


Cows are what they eat! More omega 3s in forage/feed = more omega 3-s in meat

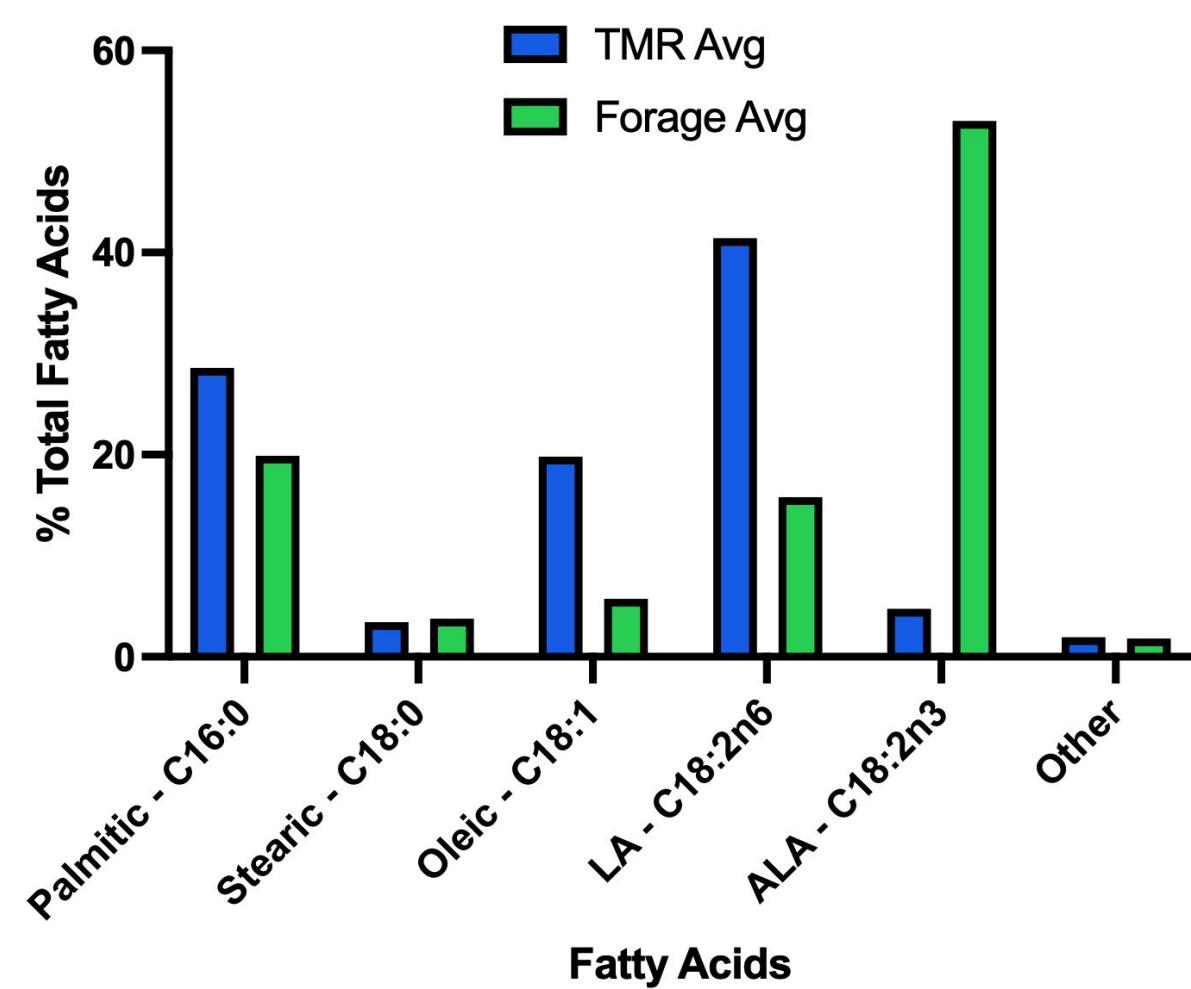


Omega Balance =
 $\text{Omega 3} / (\text{Omega 3} + \text{Omega 6})$

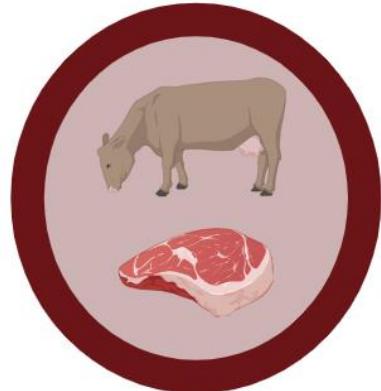
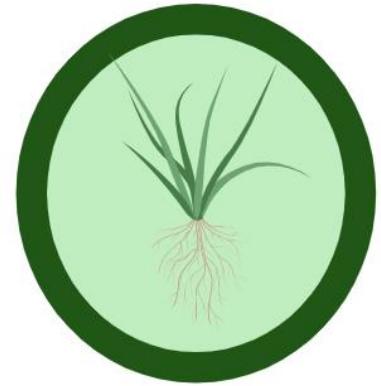
Higher omega balance =
more omega-3s



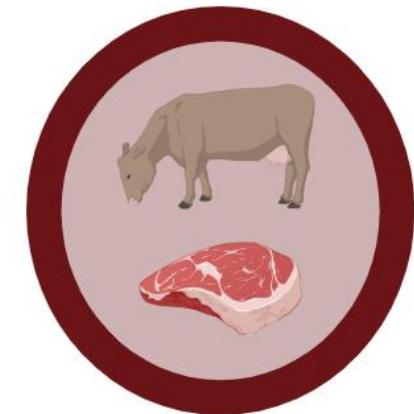
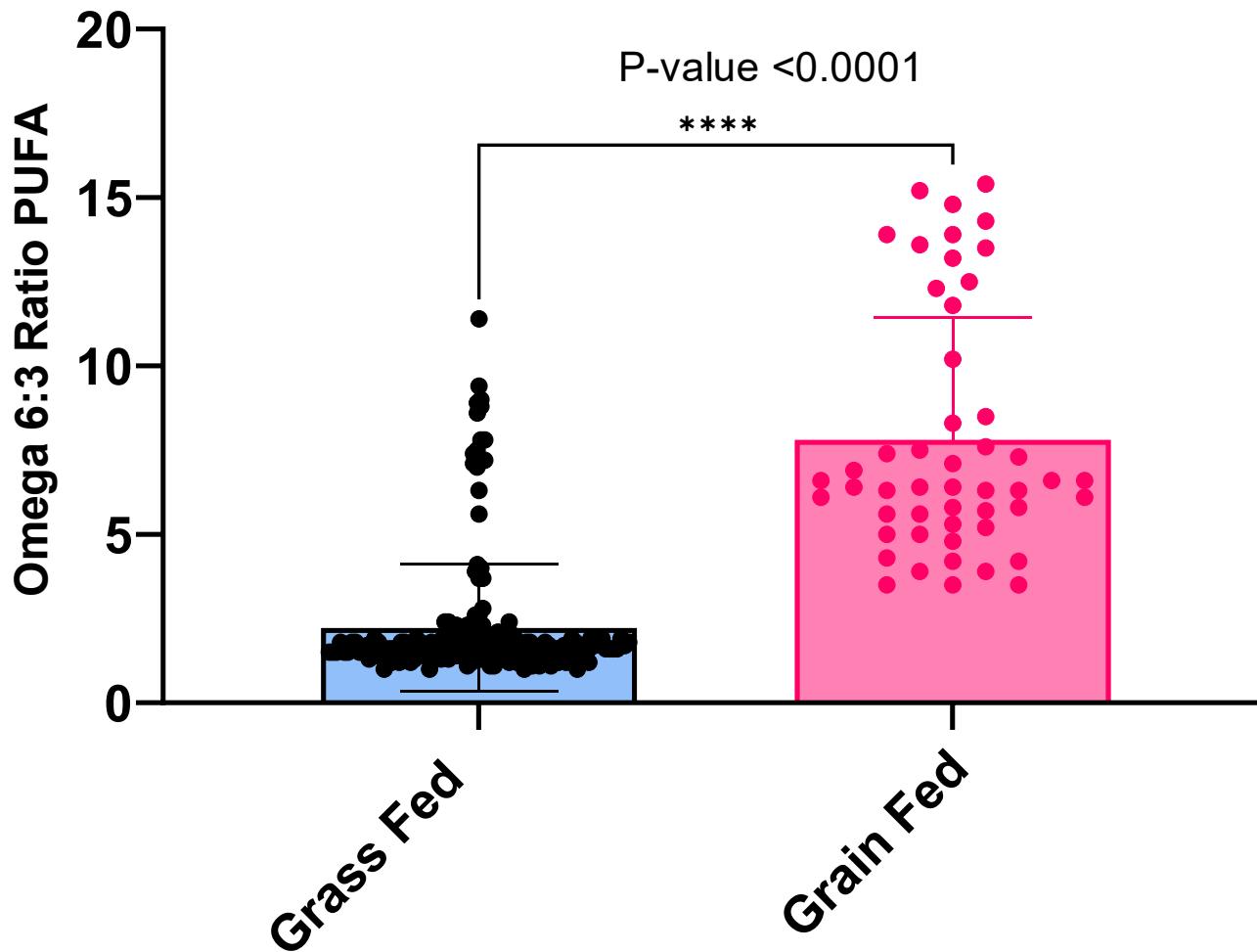
Plant Fatty Acids



Omega 6:3 Ratio



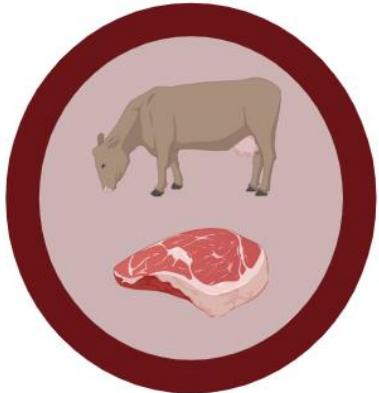
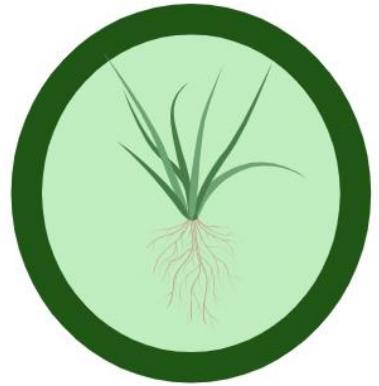
Average = 1.7
Range = 0.9-11.4



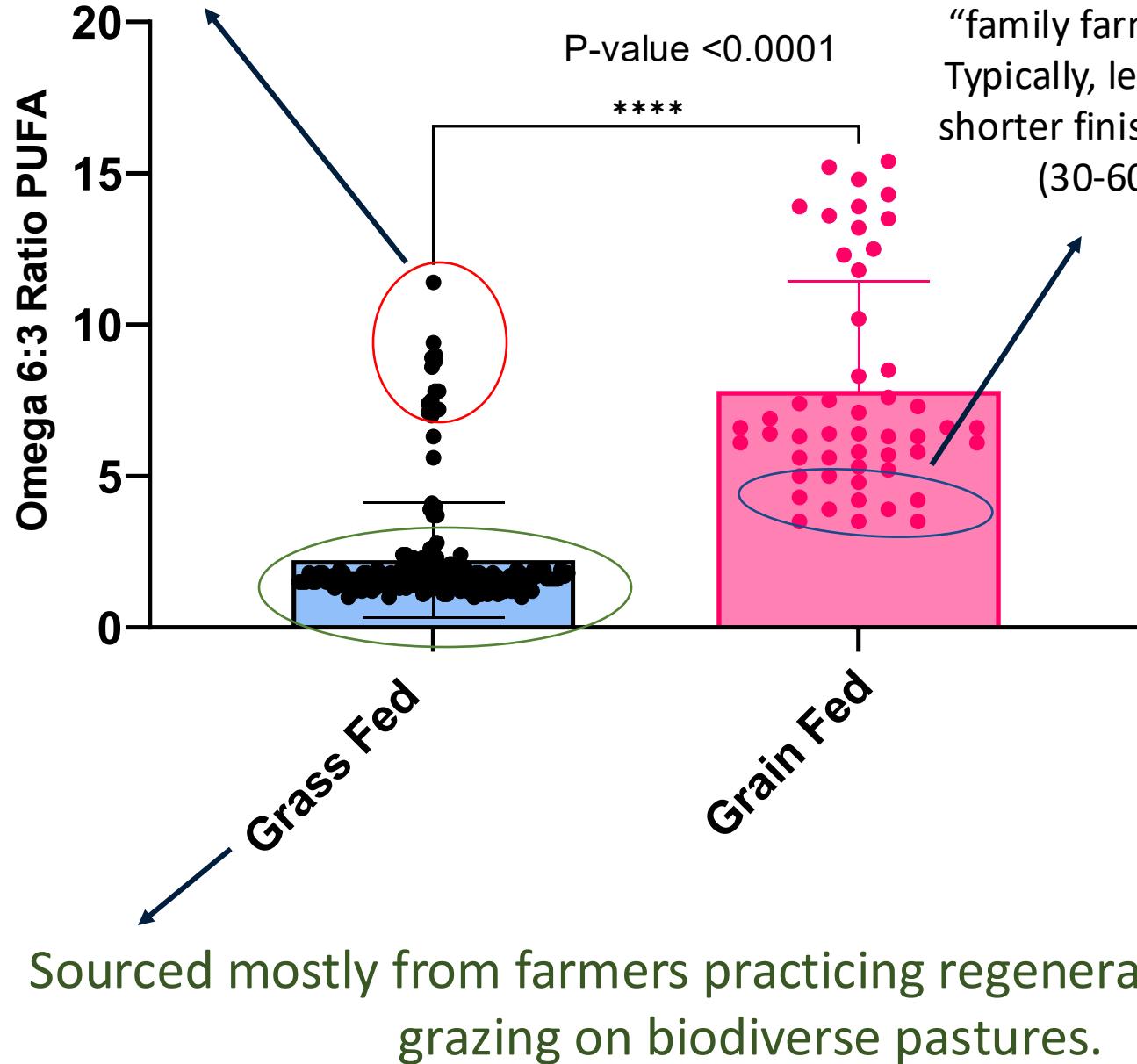
Average = 7.8
Range = 3.5-14.4

A lower omega 6:3 ratio is typically considered beneficial.
Lower levels means a higher abundance of omega-3 fatty acids.

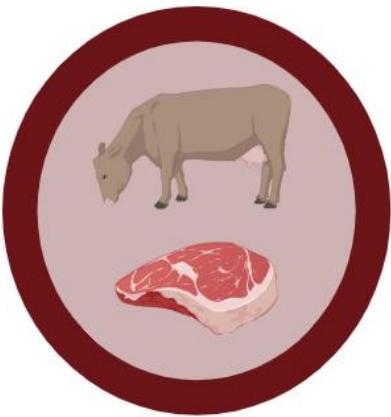
Truly grass-fed? Mostly whole-sale/grocery store sourced.



Average = 1.7
Range = 0.9-11.4

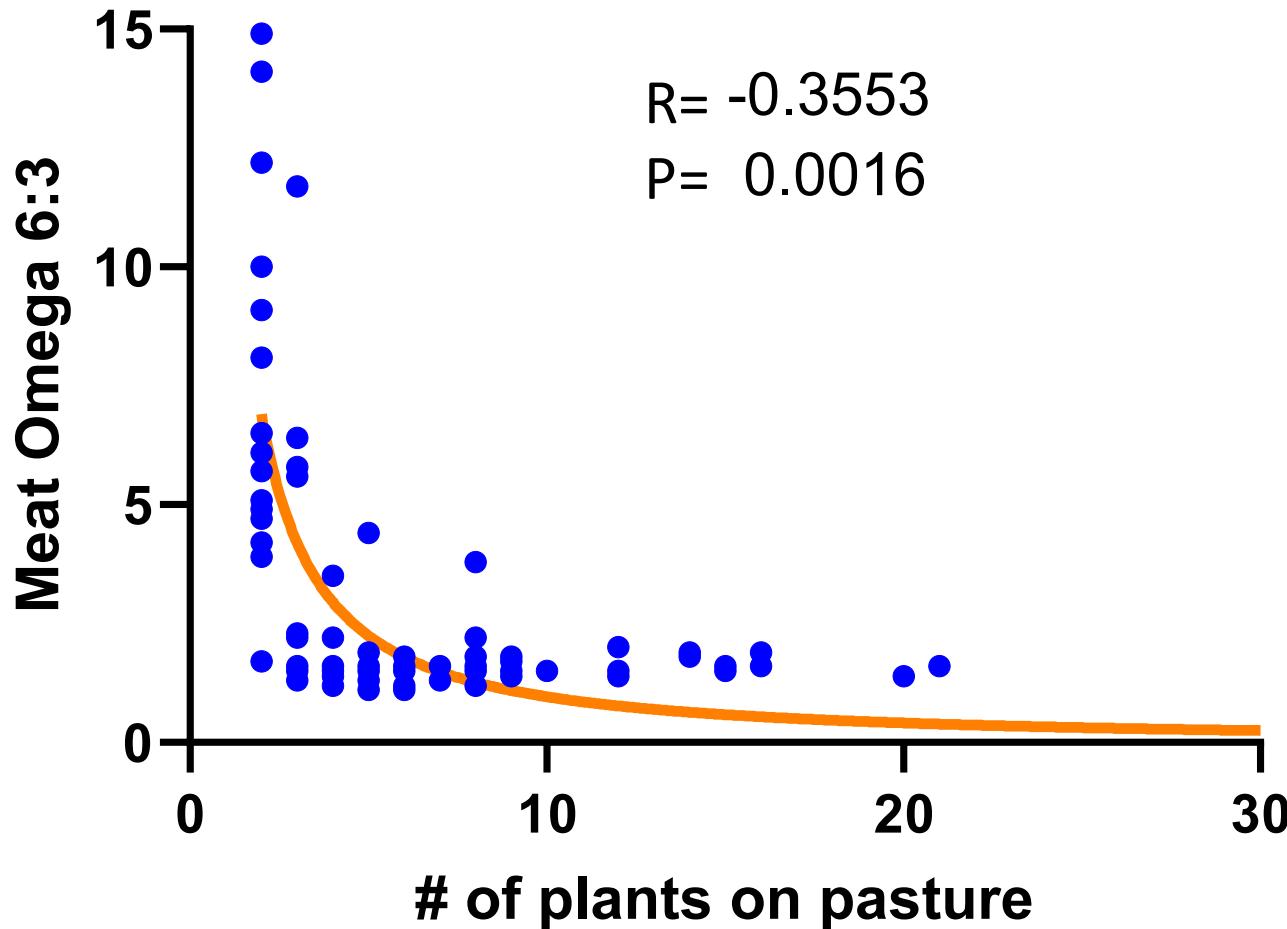


Sourced from smaller “family farm” feedlots: Typically, less grain and shorter finishing phases (30-60 days)



Average = 7.8
Range = 3.5-14.4

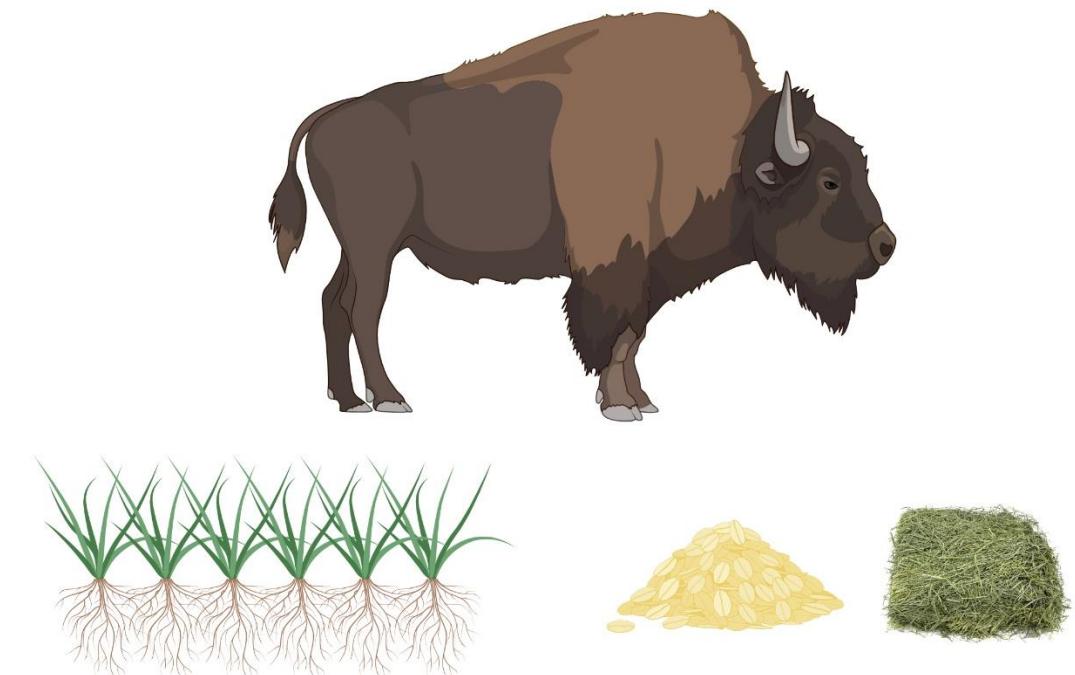
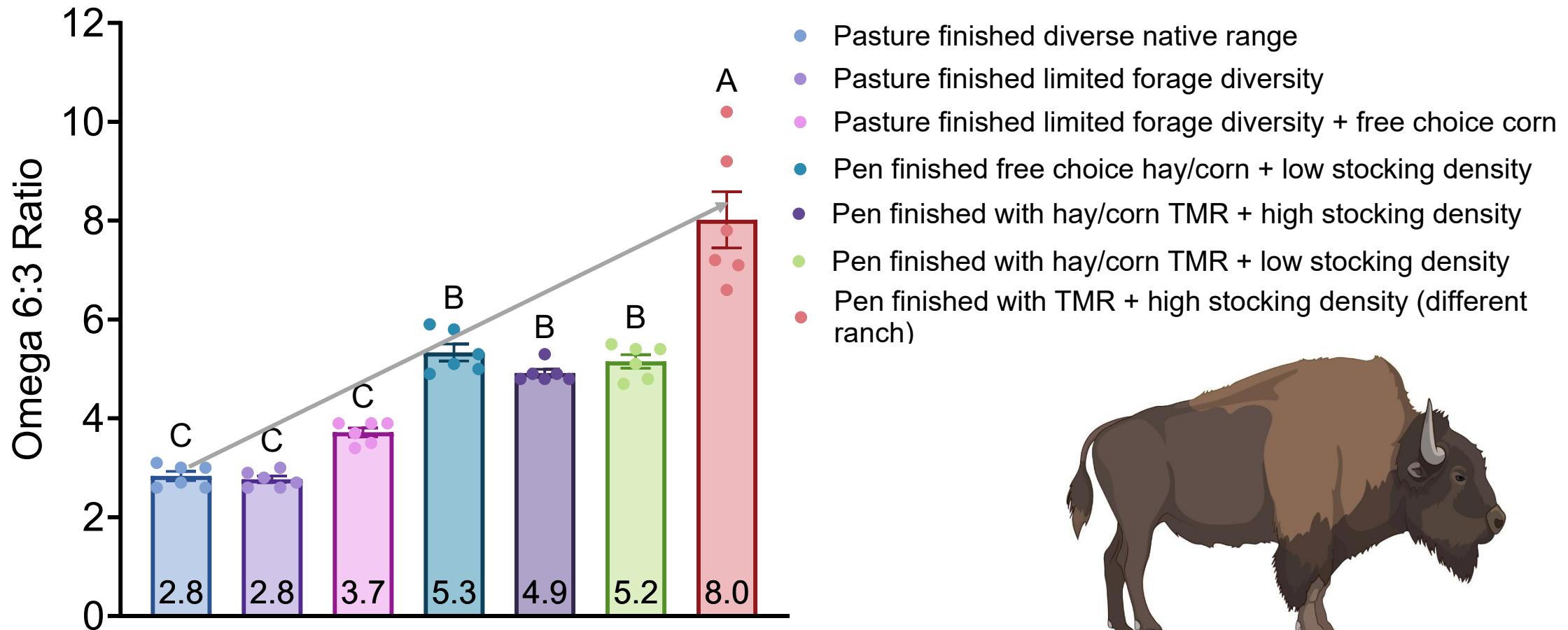
Plant Diversity vs Meat Omega 6:3



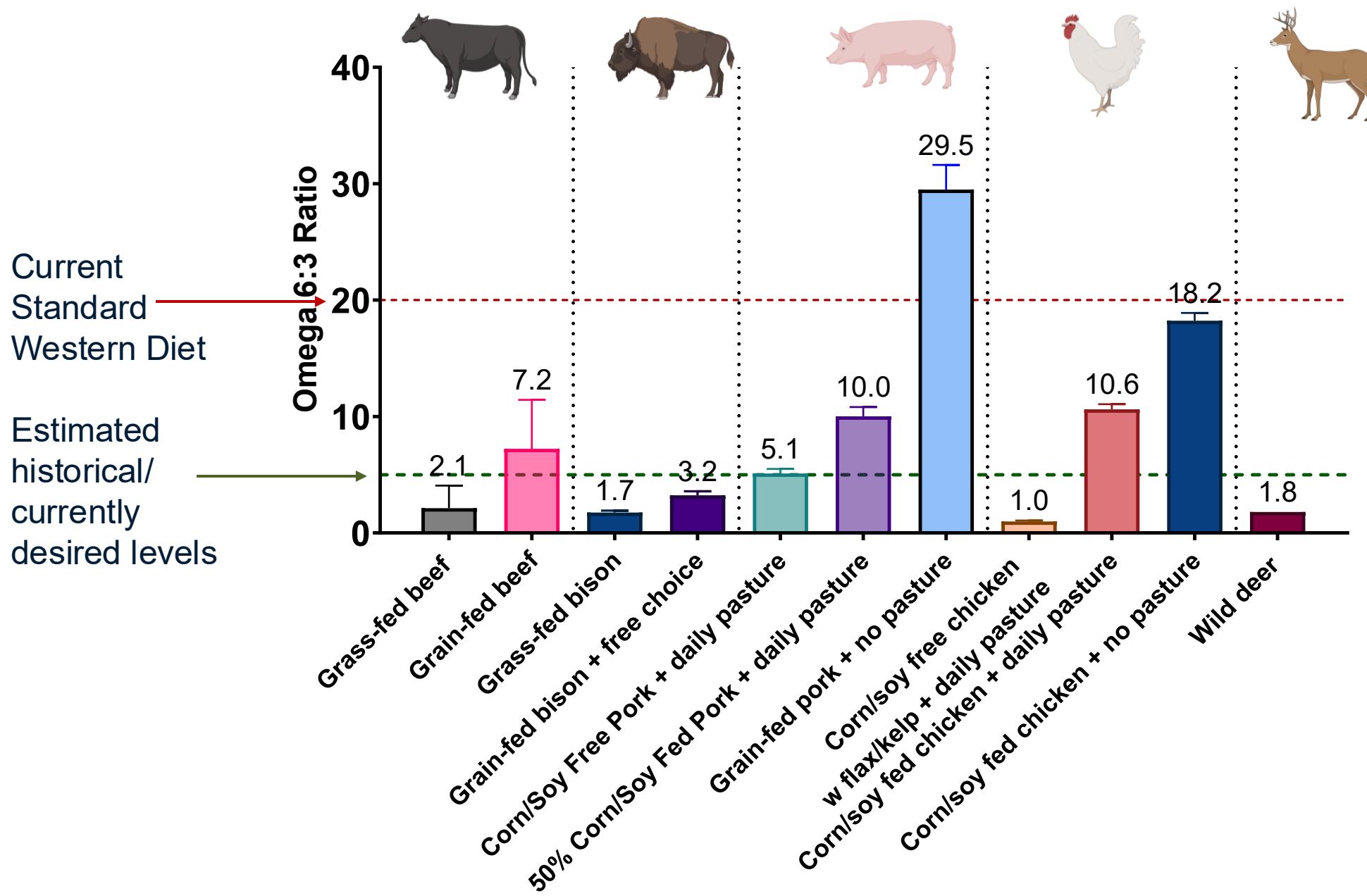
Higher plant diversity results in a better omega 6:3 profile with diminishing returns >8 plants.

A polyculture is typically also better for plant and soil health!

Similar findings are made in other species



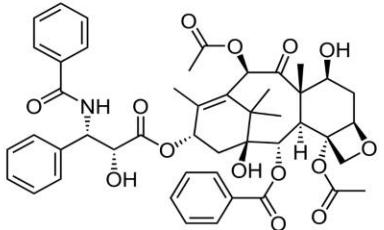
Similar findings are made in other species



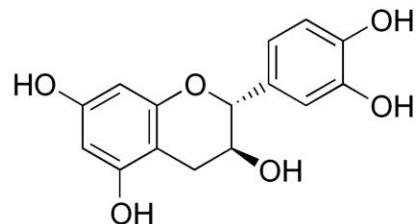
Phytonutrients (“antioxidants”): transfer from plant to animal?



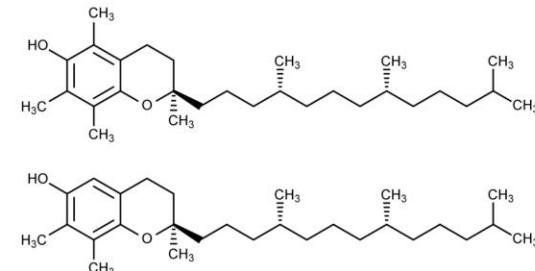
Plants respond biochemically to sunlight, moisture, nutrients, other plants, and herbivores by producing phytochemicals.



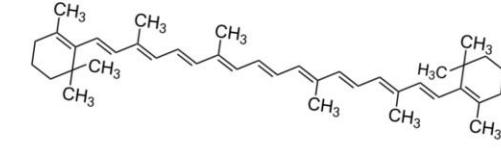
Polyphenols



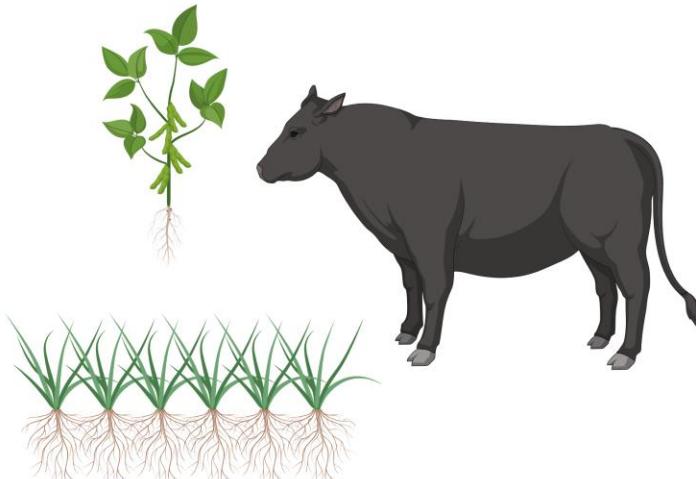
Cinnamic acid



Flavanols

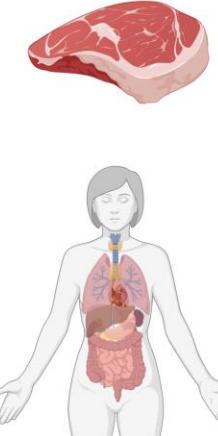


Benzoic acids

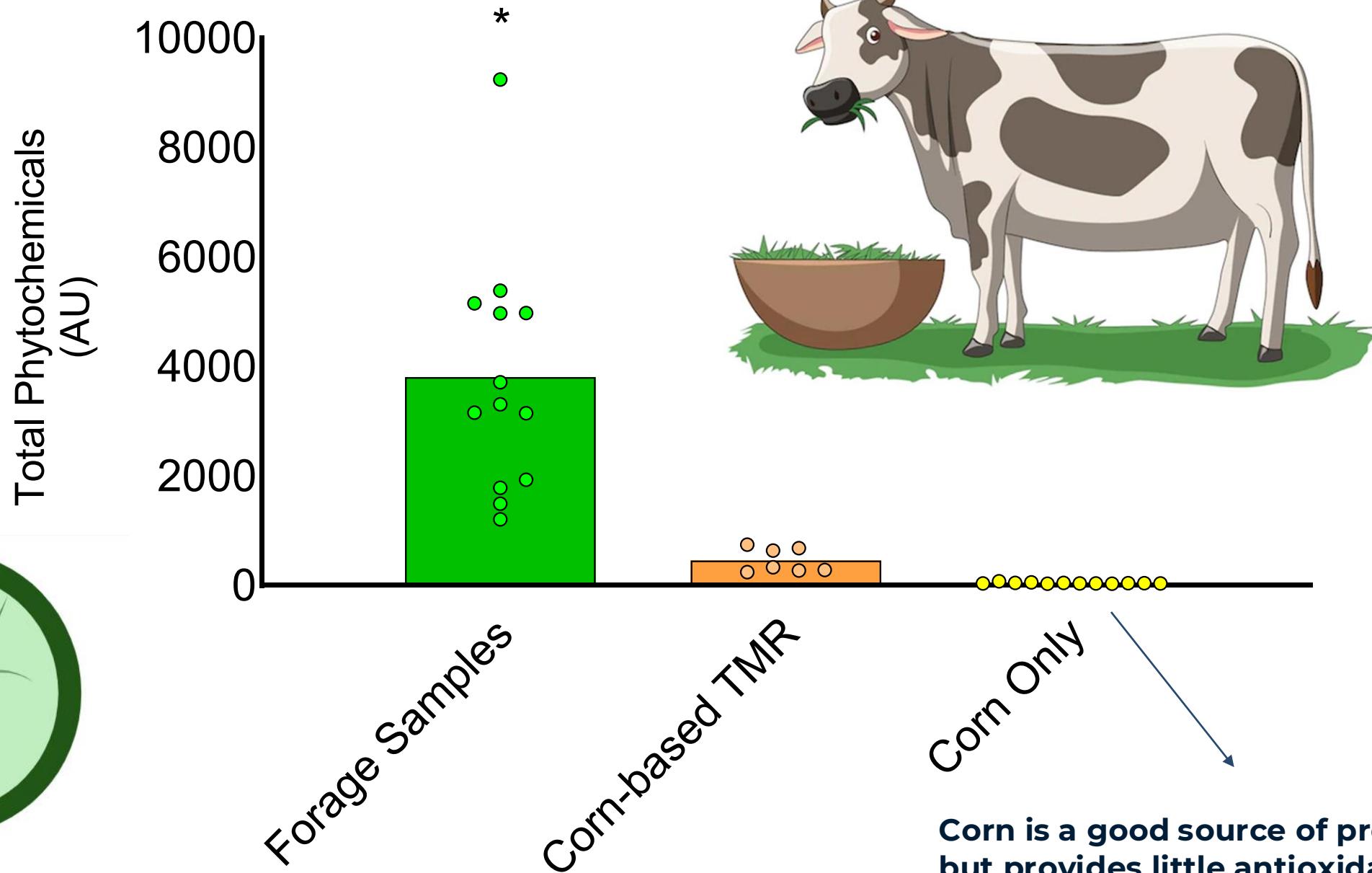
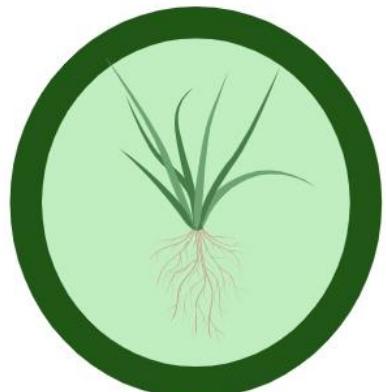


These compounds are upcycled
from forages to meat.

Potentially anti-inflammatory,
anti-bacterial, anti-oxidant.



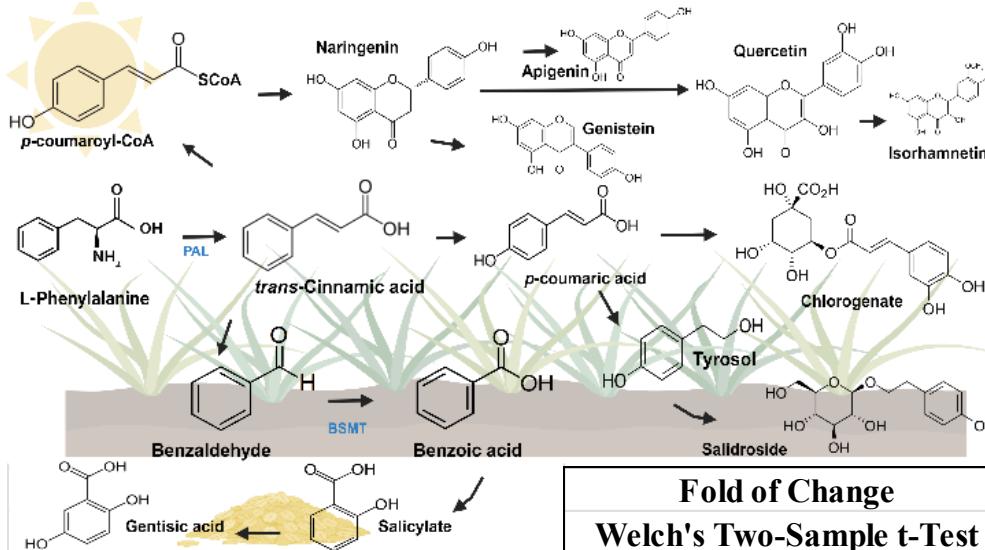
Cows are what they eat... Phytochemical richness of forages



Corn is a good source of protein/energy
but provides little antioxidants

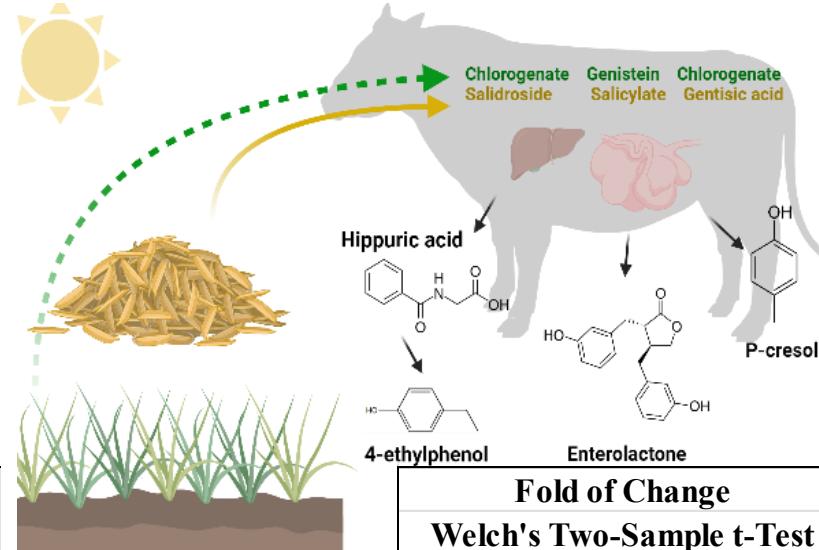
Cows eat polyphenols from plants we cannot eat and transform them into animal versions of antioxidants...

Several of these are like the antioxidants found in our bodies (we are both mammals)!



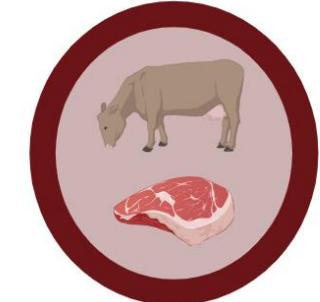
Sub Pathway	Biochemical Name	Fold of Change Welch's Two-Sample t-Test	
		Pasture/TMR	TMR/grass-fed
Xenobiotics/Phenolic Metabolism	Chrysoeriol	45.70	
	Salidroside	111.71	
	Apigeninidin	70.12	
	Rosmarinate	70.75	
	Rutin	28.78	
	Feruloylquinate (3)	79.39	
	Luteolin 7-o-glucoside	889.84	
	Salicylate	52.13	
	Quercetin-3-glucuronide	15.95	
	Gentisic acid-5-glucoside	52.58	
	Coumaroylquinate (4)	237.43	
	Genistein	86.55	
	Isorhamnetin 3-rutinoside	291.17	
	Chlorogenate	276.65	
	Formononetin	103.88	

276x higher
in grass vs
TMR



Biochemical Name	Fold of Change Welch's Two-Sample t-Test	
	Bf Grass	Bf Grain
P-cresol sulfate	1.16	
Enterolactone	0.96	
2,6-dihydroxybenzoic acid	4.71	
Hippurate	1.99	
Equol sulfate	1.16	
Stachydrine	13.91	
Homostachydrine	11.63	
Cinnamoylglycine	1.97	
Fagomine	0.69	
Ergothioneine	2.79	
Phenol sulfate	2.44	
4-methylcatechol sulfate	0.26	
Catechol sulfate	6.00	
Piperidine	0.14	
4-ethylphenylsulfate	5.36	

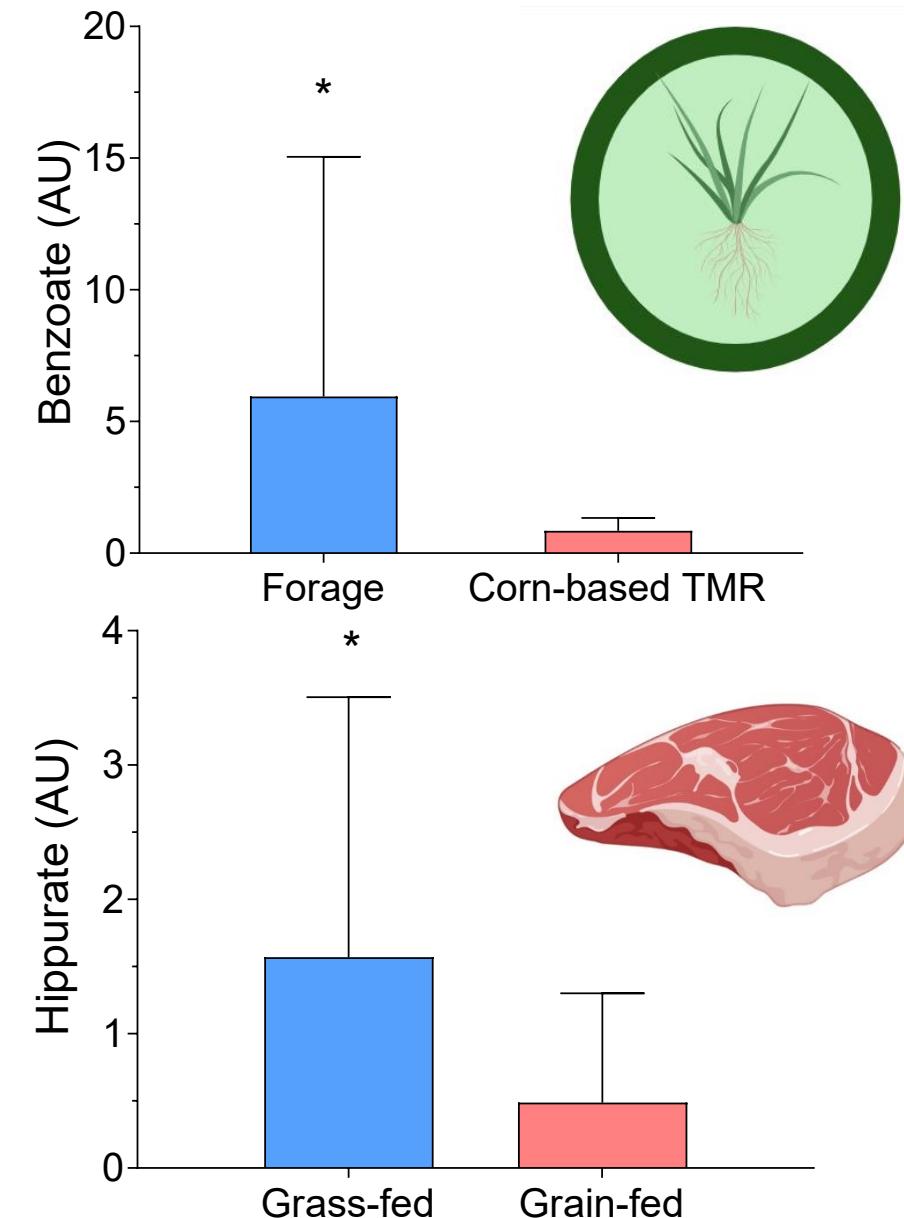
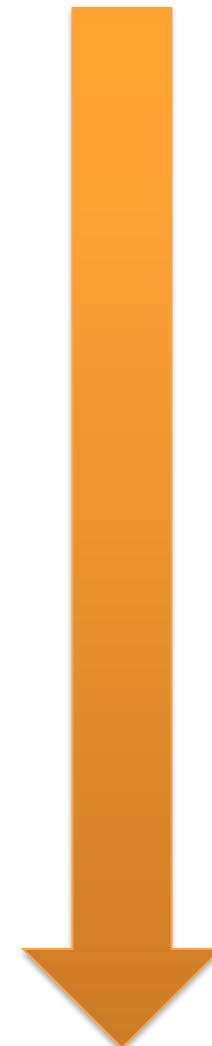
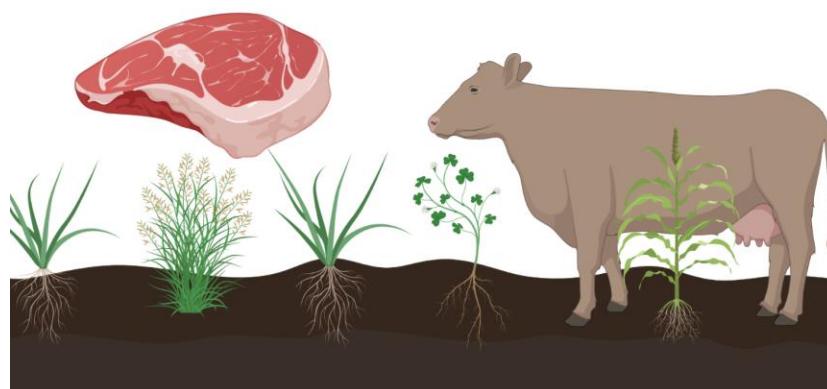
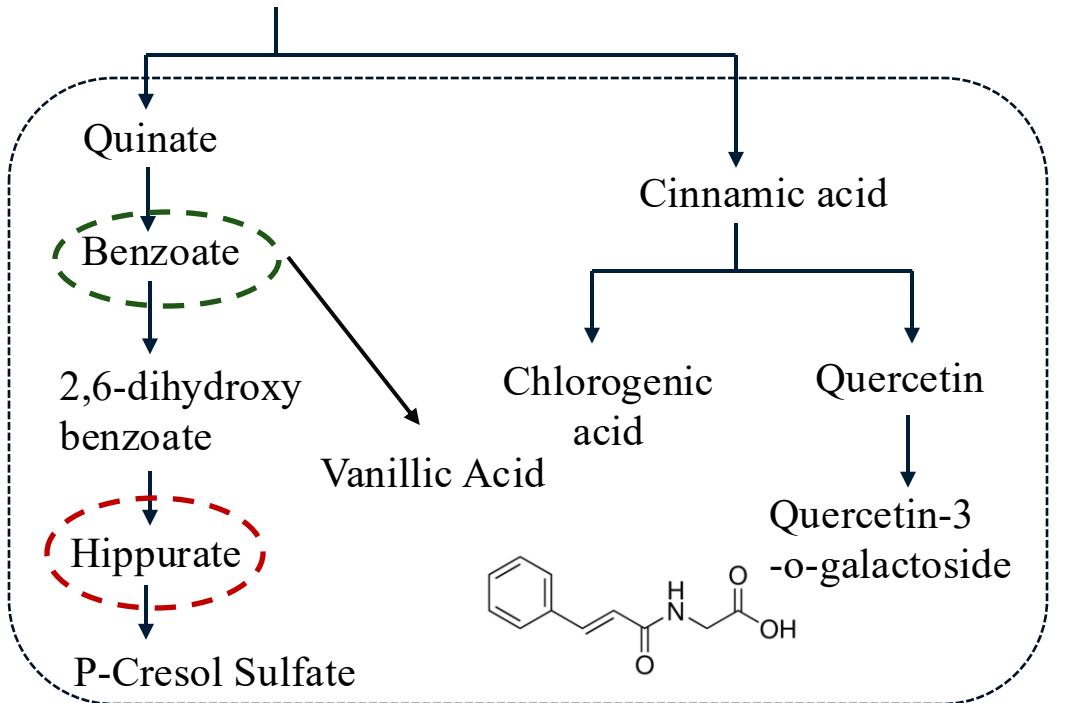
↑ TMR/
grain-fed



6x higher in
grass-fed
beef

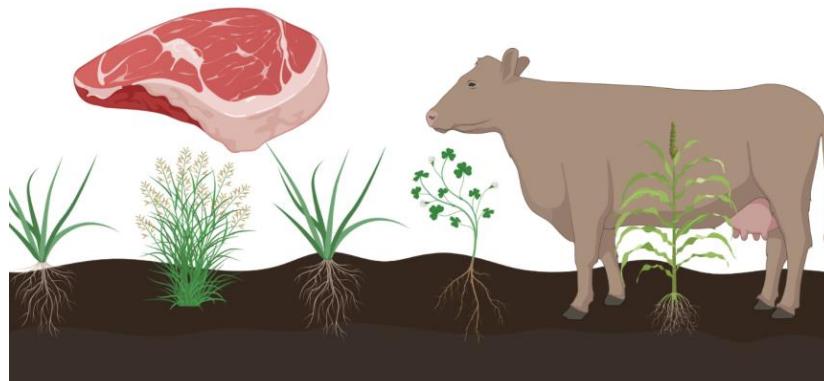
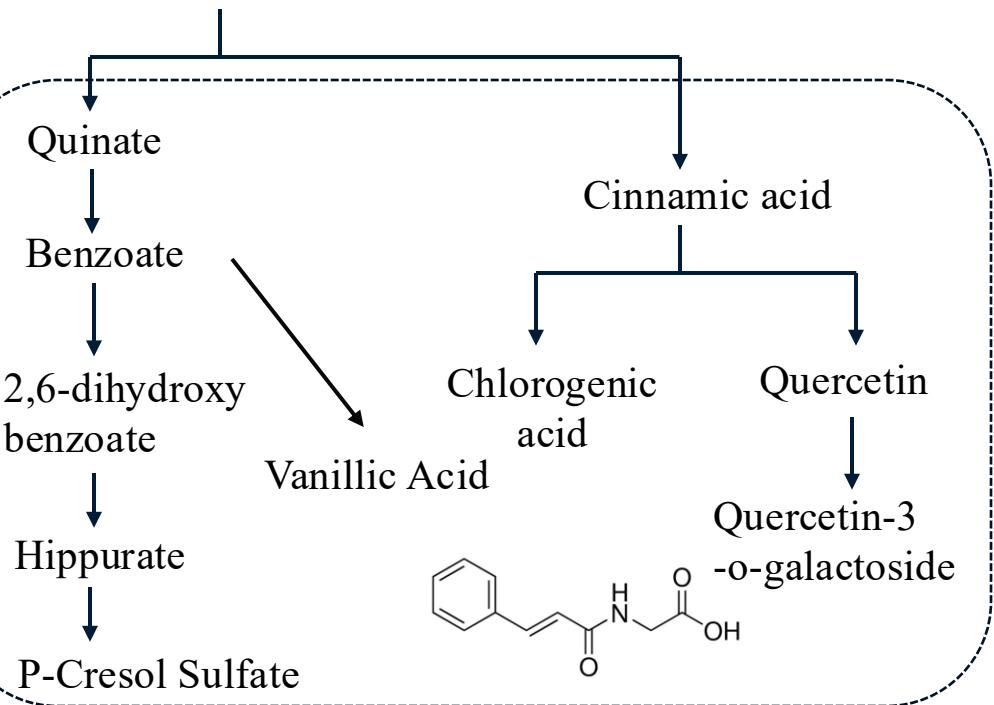
Transfer from forage to animal!

Plant phenolic compounds

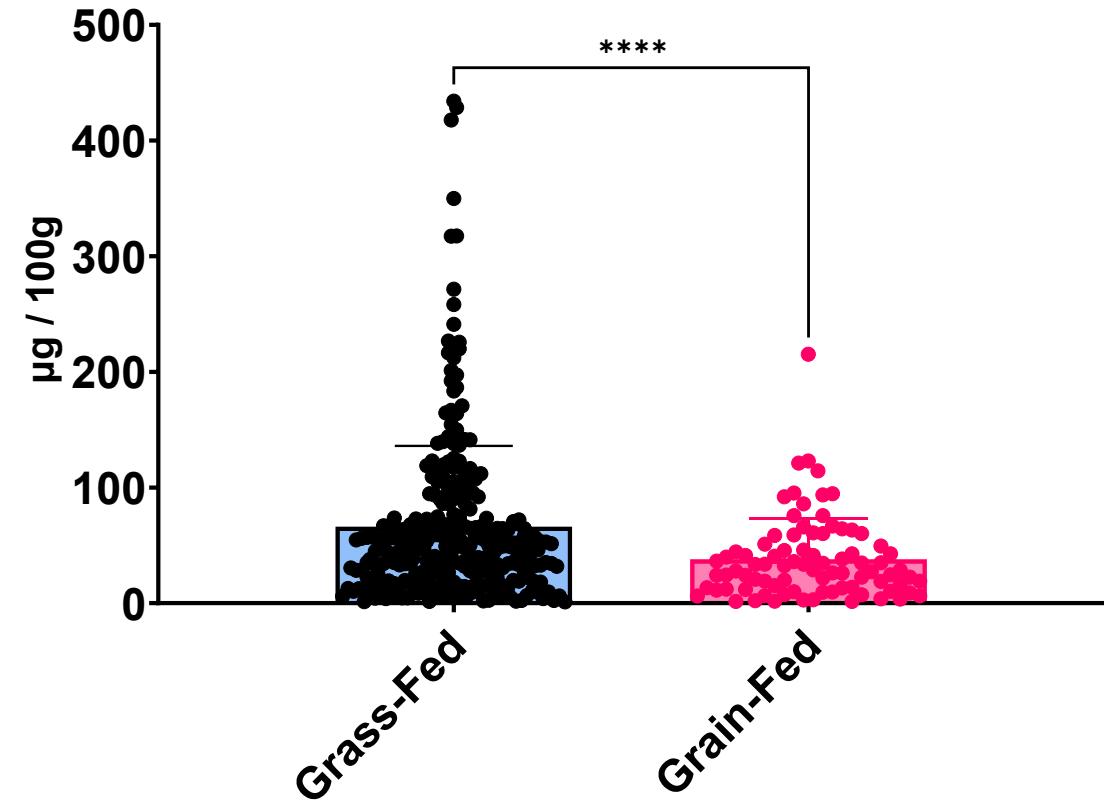


Phytochemicals

Plant phenolic compounds

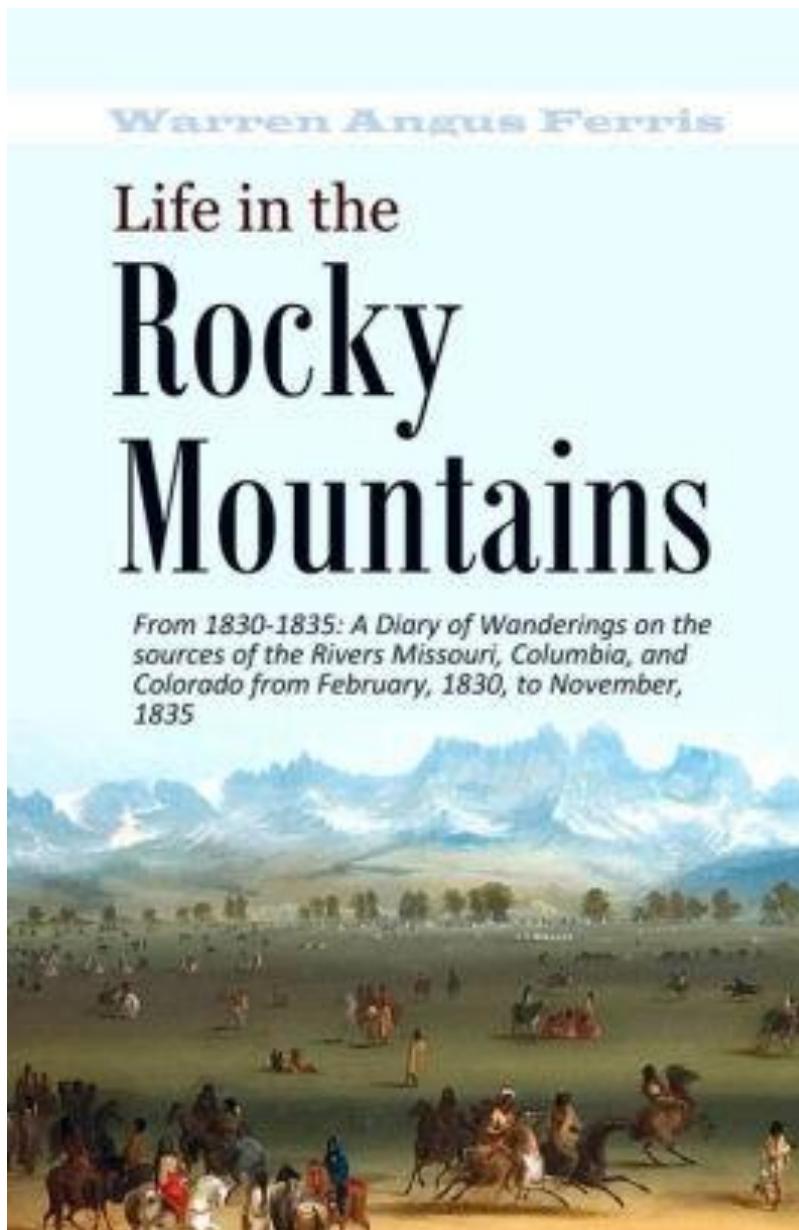


Hippuric acid



Major anti-oxidant. Associated with reduced odds of metabolic syndrome in humans. Biomarker of phenolic intake in mammals (cows and humans) as this compound is produced from phenols.

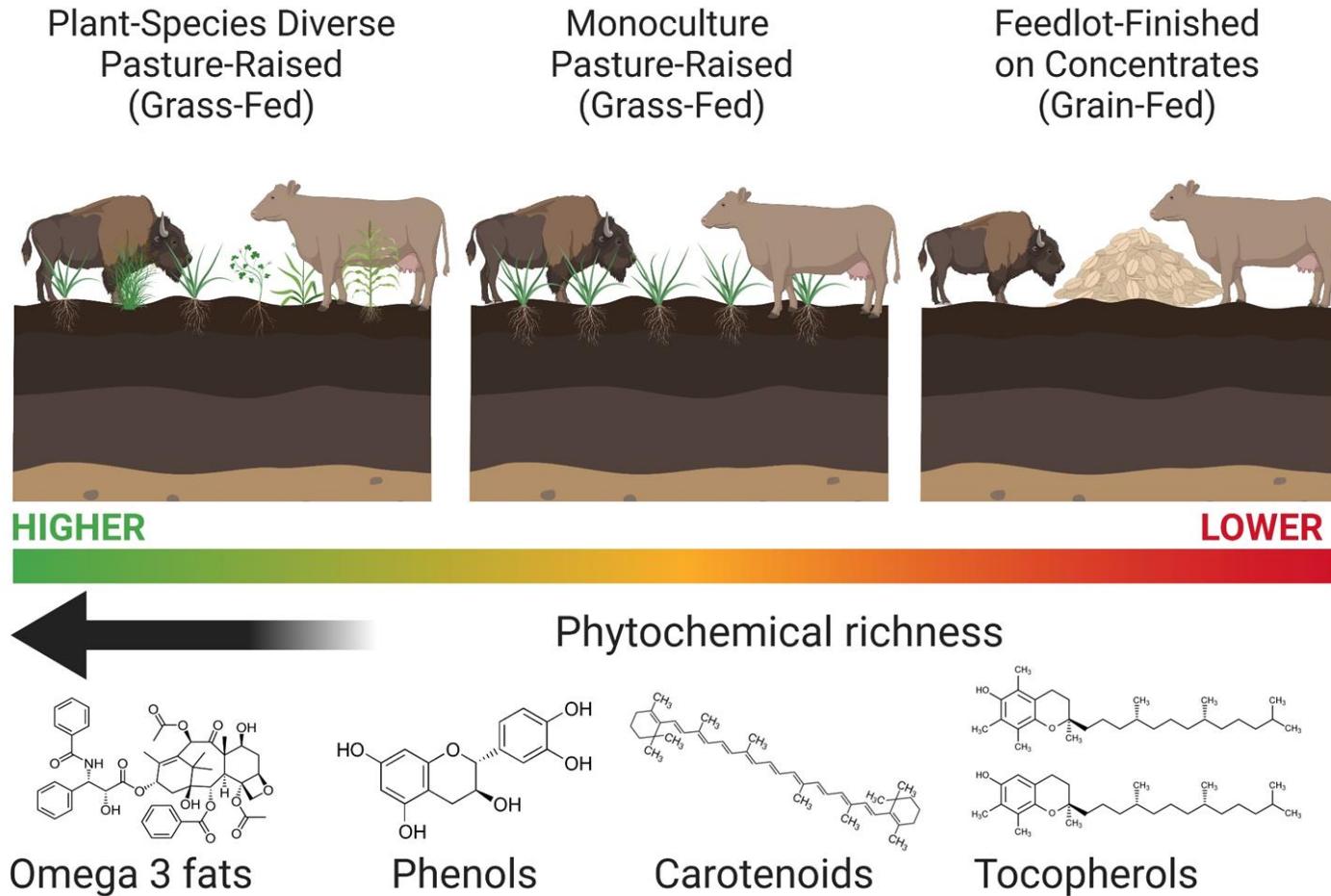
Something humans already knew for a while.... traditional wisdom



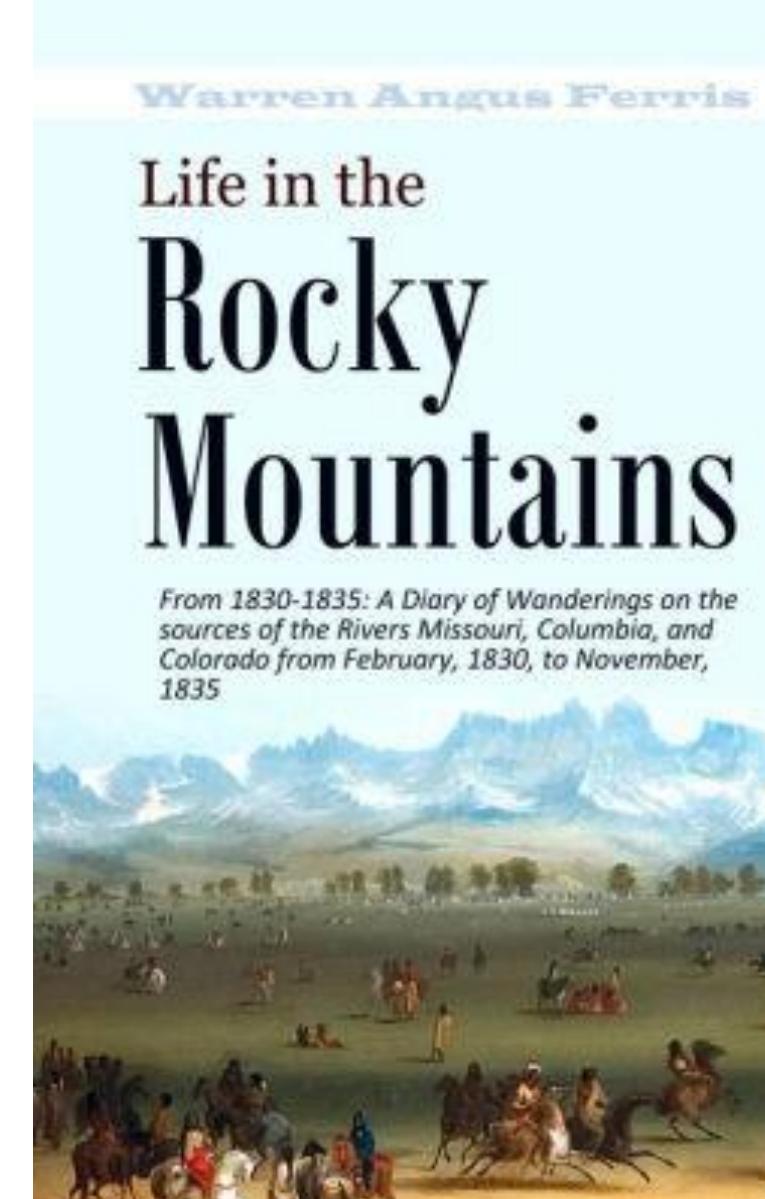
In *Life in the Rocky Mountains*, Warren Angus Ferris recounts his adventures in the headwaters of the Missouri, Columbia, and Colorado Rivers from 1830 to 1835, where he encountered vast herds of bison. During those adventures Ferris' crew fed on bison, as indigenous peoples had done for ages. He notes that bison in poor flesh were on the worst diet imaginable, but as the animal fed on diverse mixes of plants, no other meat could compare. "With it we require no seasoning; we boil, roast, or fry it, as we please, and live upon it solely, and what seems most singular, we never tire of or disrelish it, which would be the case with almost any other meat."

Fast forward 200 years to modern science....

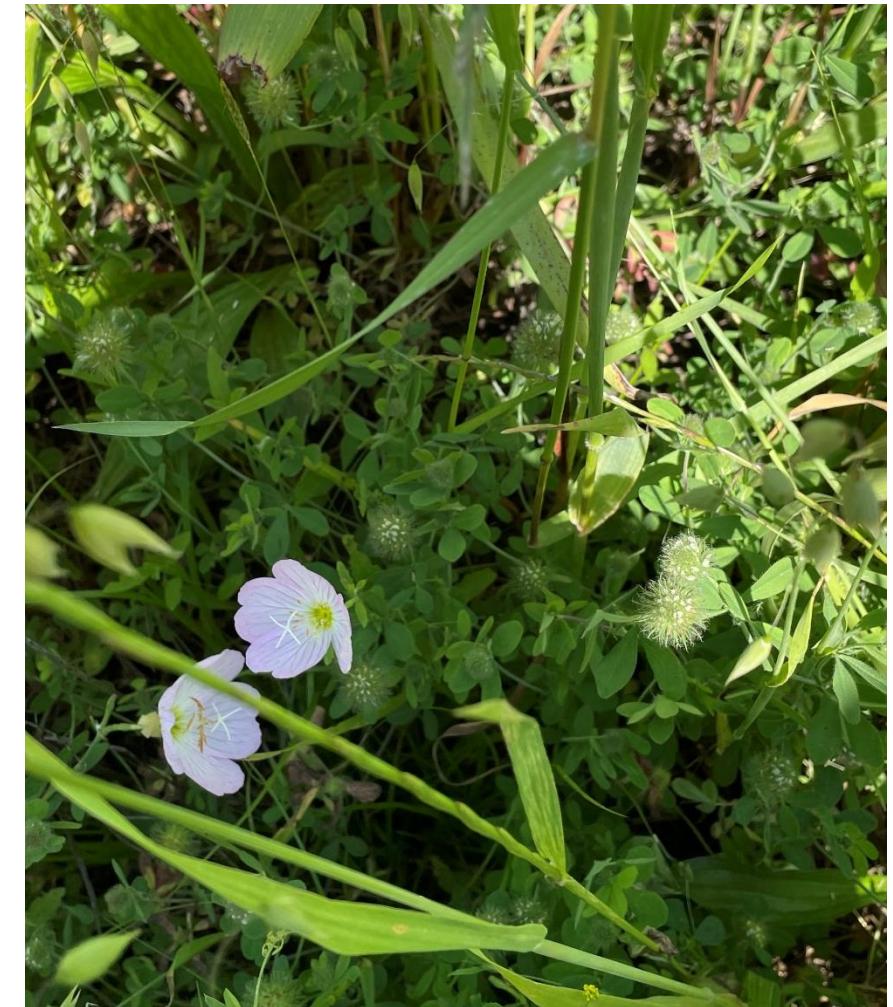
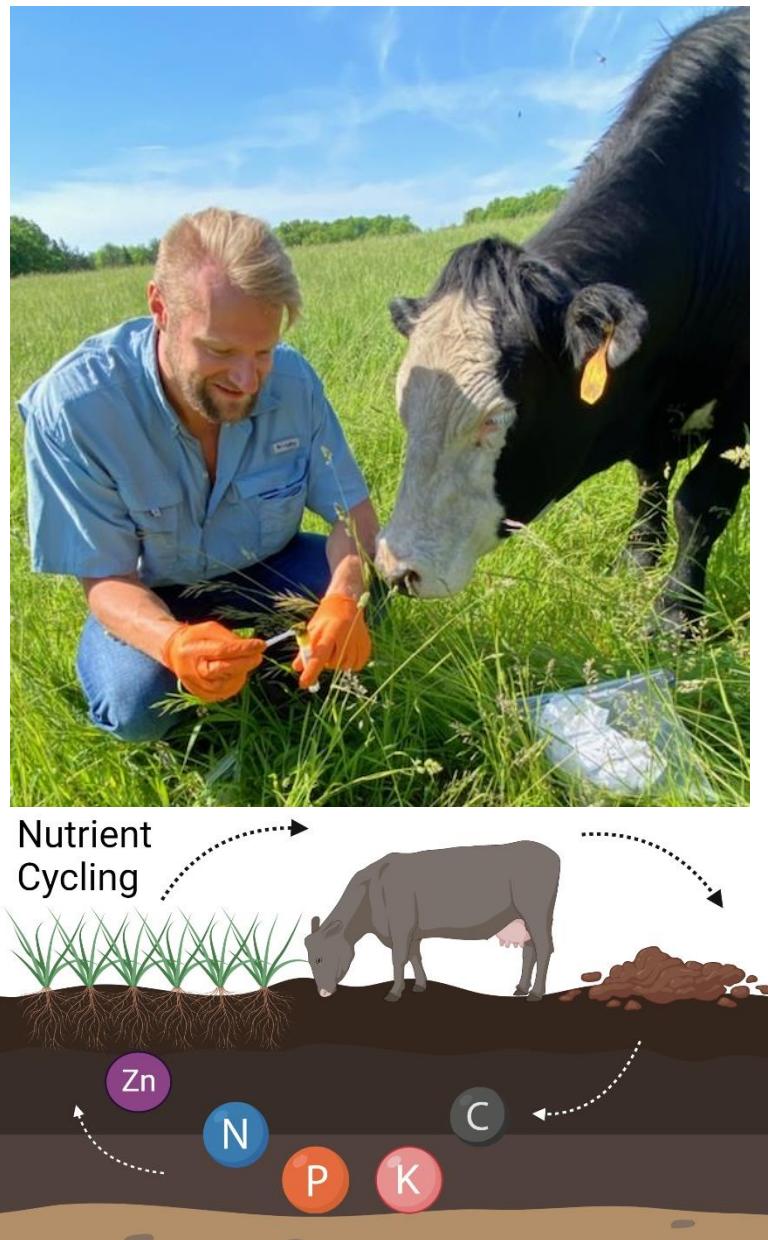
Angus Ferris was likely referring to the phytochemical richness of the meat!



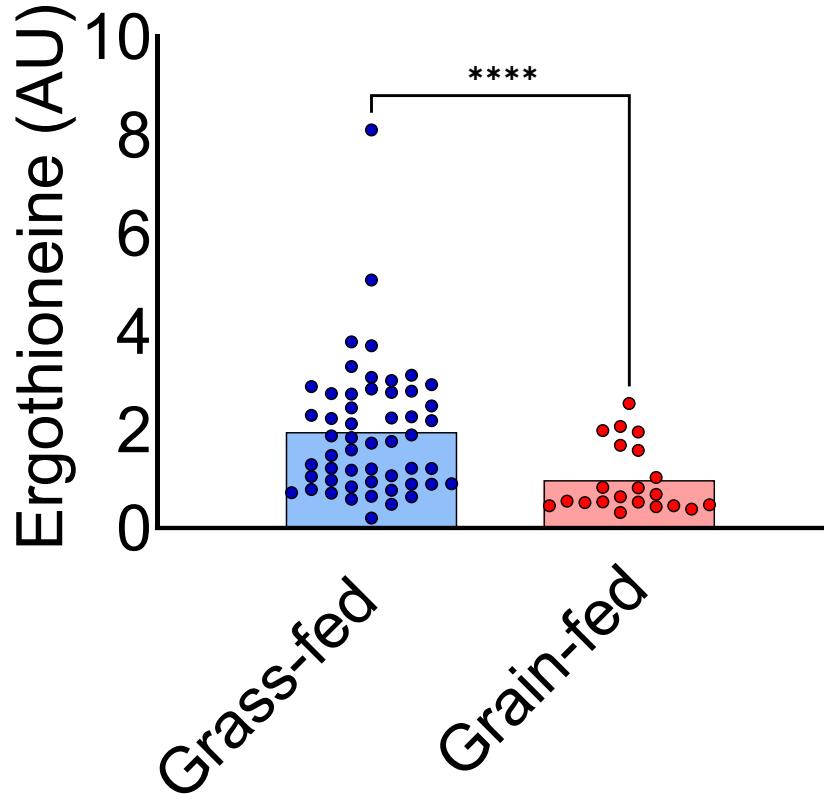
The flavor of meat (and milk) is influenced by phytochemical richness of the animal's diet. These phytochemicals also have potential health-promoting effects. Flavor and health are related?



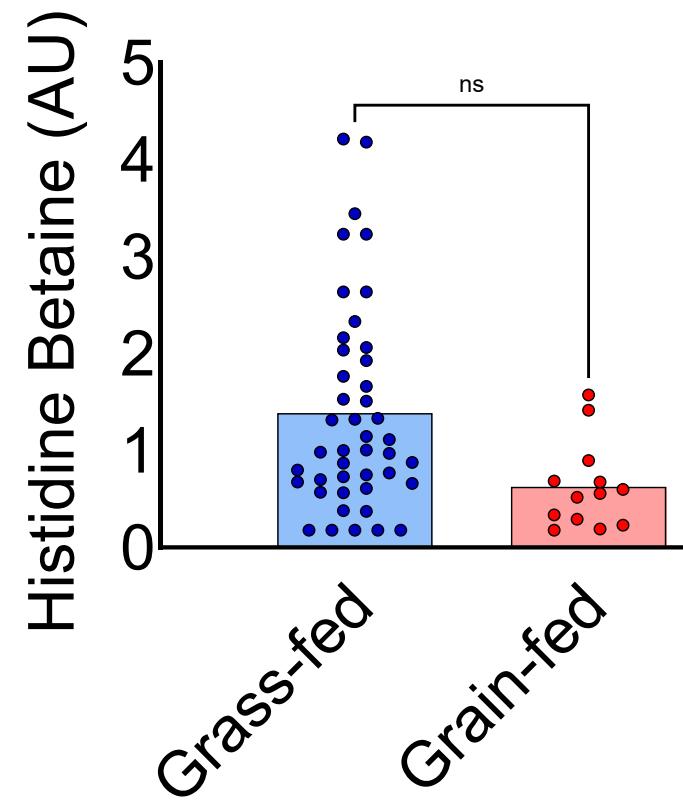
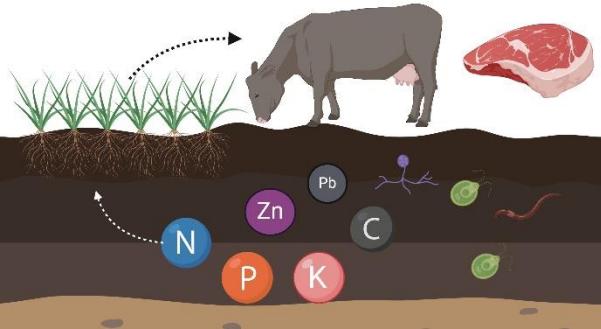
Relationships with soil health?



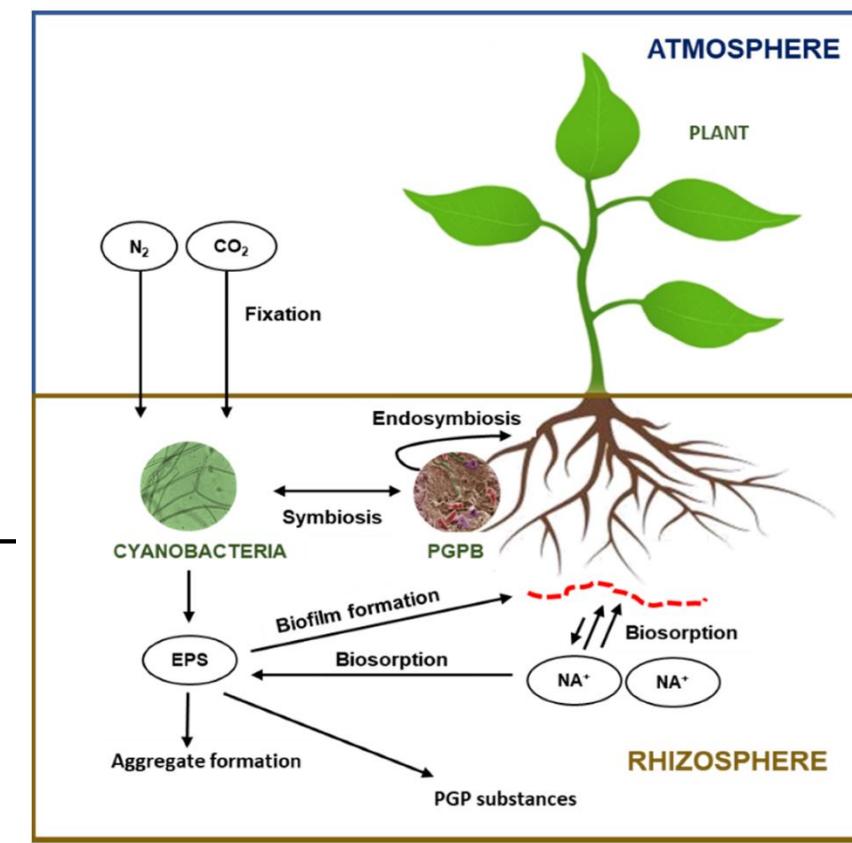
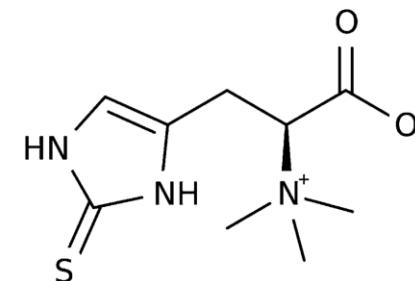
More “life” in the soil = more soil produced antioxidants in meat



Produced only by soil-fungi;
Anti-oxidant, anti-inflammatory



Metabolite of Ergothioneine:
Anti-oxidant, anti-inflammatory



Ergothioneine produced in relatively few organisms, notably Actinomycetota, Cyanobacteria, and certain fungi in the rhizosphere.

<https://doi.org/10.1038/s41538-025-00471-2>

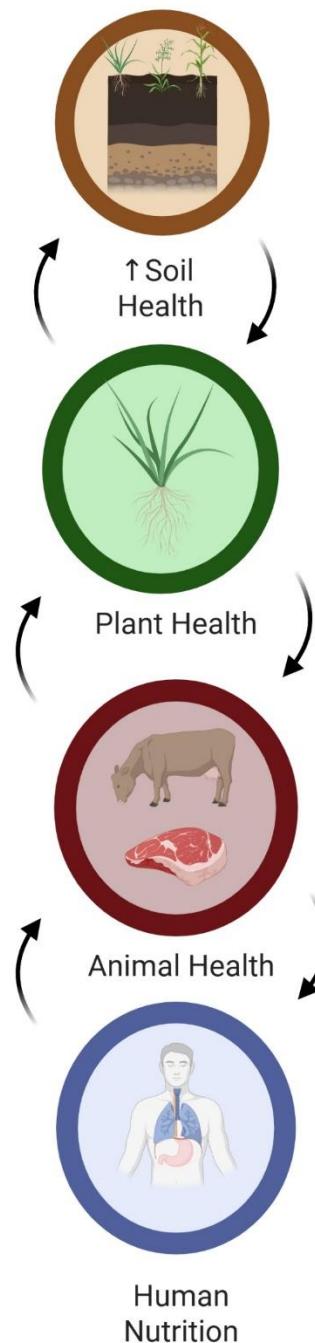
Soil and pasture health underlie improved beef nutrient density determined by untargeted metabolomics in Southern US grass finished beef systems



Check for updates

Muhammad Ahsin¹, Matt H. Poore², Johnny Rogers², Alan Franzluebbers³, Sierra N. Young⁴,
Scott L. Kronberg⁵, Frederick D. Provenza⁶, James R. Bain⁷ & Stephan van Vliet^{1,7}

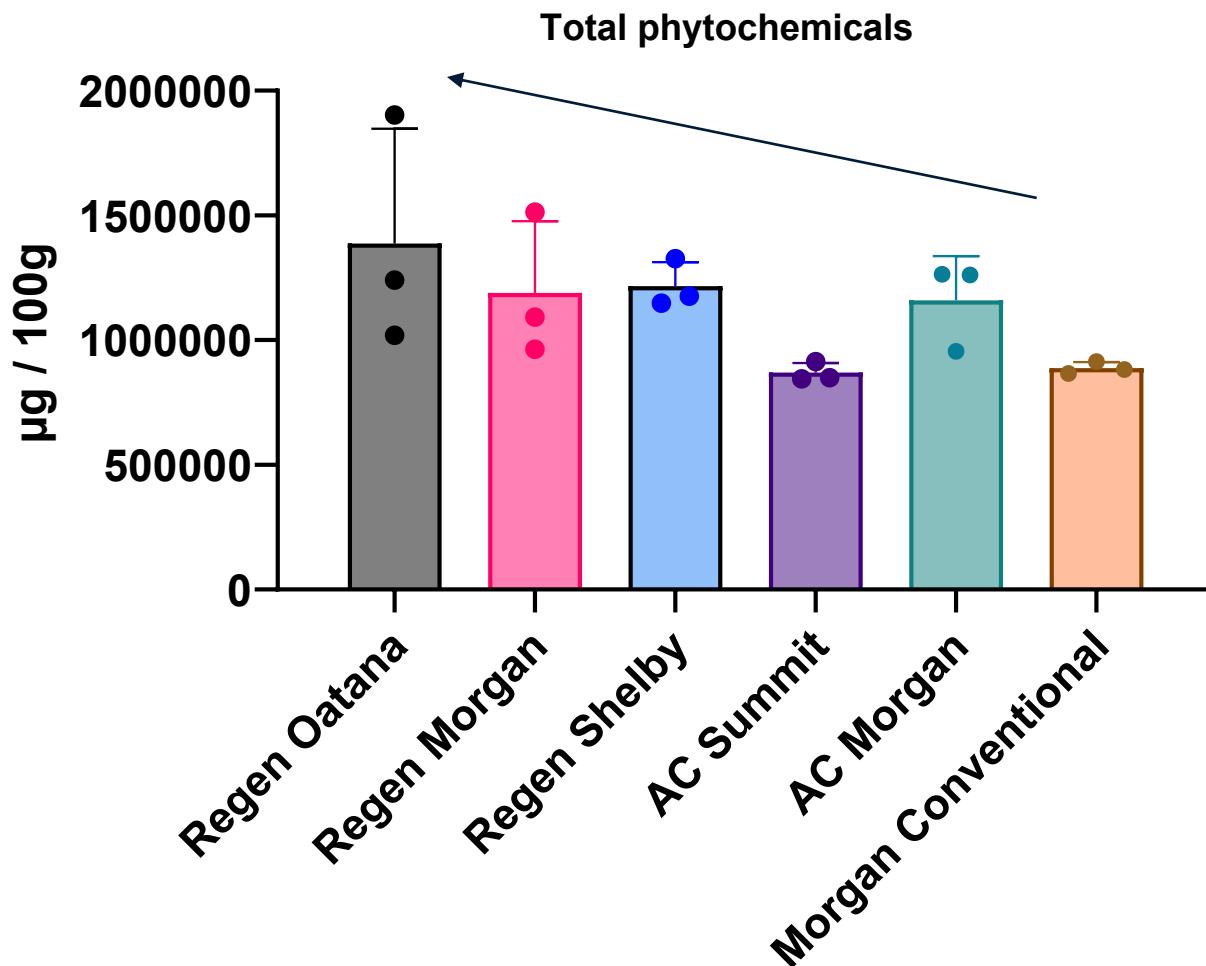
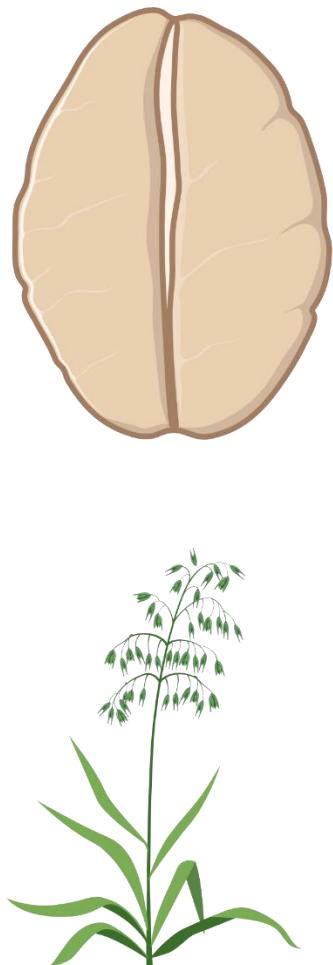
As concerns regarding beef production on human and environmental health increase, interest in sustainable practices has grown. This study compared soil, plant, and meat samples from three Southern US grass-fed beef systems to a paired grain-fed beef system to assess soil health, forage phytochemical richness, and meat nutritional composition. Soil samples from pasturelands had 1.4 times higher organic matter and 1.7- to 3.0-fold higher levels of minerals like potassium, phosphorus, and calcium compared to paired feed croplands. Grass-fed beef contained 3.1-fold higher phytochemical antioxidants than grain-fed beef, resulting from a 118.2-fold higher phytochemical content in forage. Vitamins A and E in grass-fed beef were also 2.9- and 4.2-fold higher, respectively. Urate levels were 2.0-fold higher in grass-fed samples, while homocysteine and 4-hydroxynonenal glutathione, associated with reduced metabolic health, were elevated in grain-fed samples. The study provides evidence of the beneficial effects of grass-fed beef systems along the soil-plant-animal-human nutrition continuum.



Nutrient density data on grains



Oats from regenerative vs conventional systems



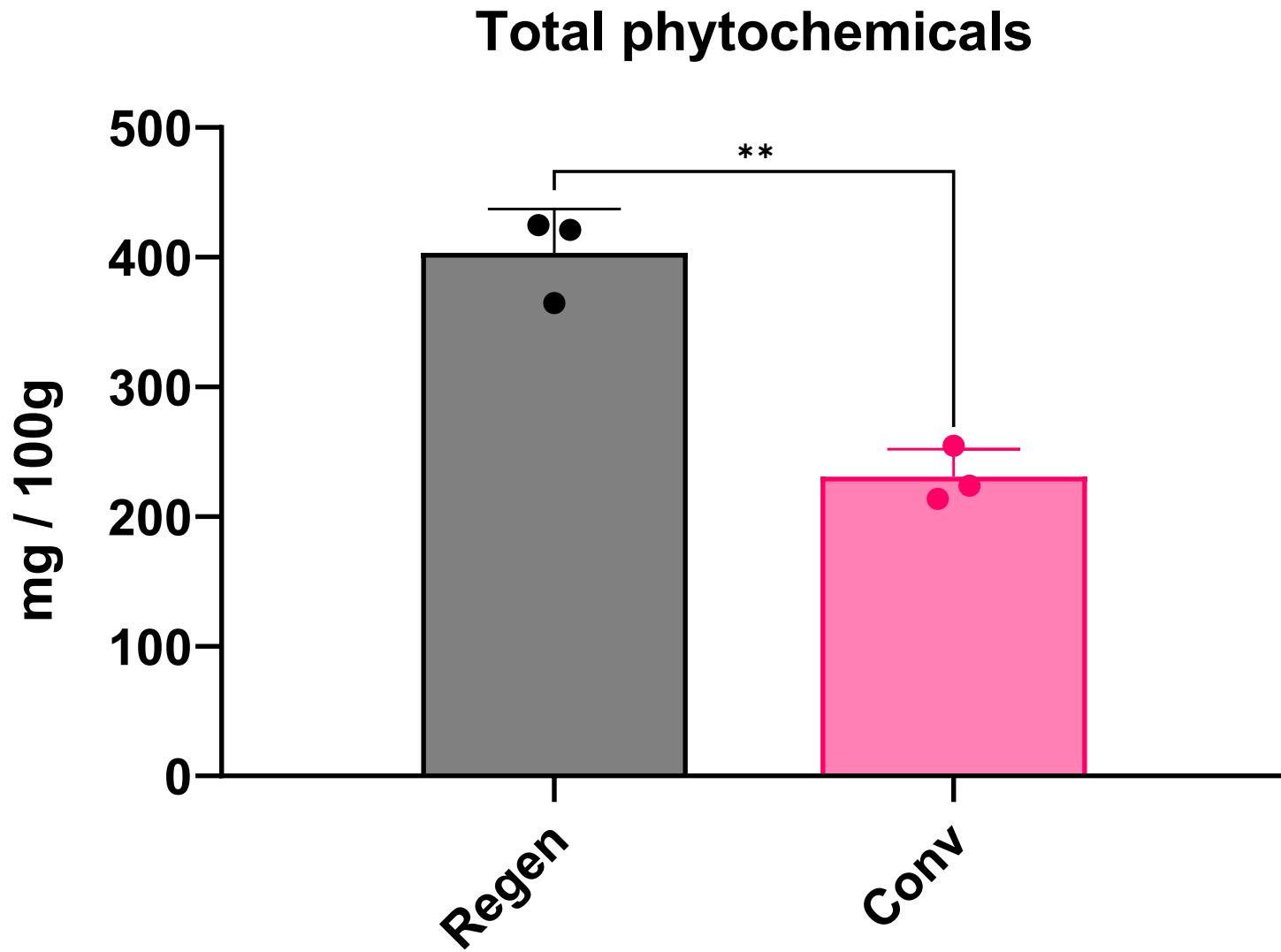
The “regenerative” systems included practices such as:

- Minimal tillage
- Organic soil amendments
- Multi-cropping
- Organic fertilizer
- Soil inoculants



Soil microbes can enhance phenolic synthesis in plants by through root exudation patterns and can influencing metabolic pathways through hormonal and enzymatic signaling. More “life in the soil” can increase phytonutrient contents in crops.

Buckwheat from regenerative vs conventional systems



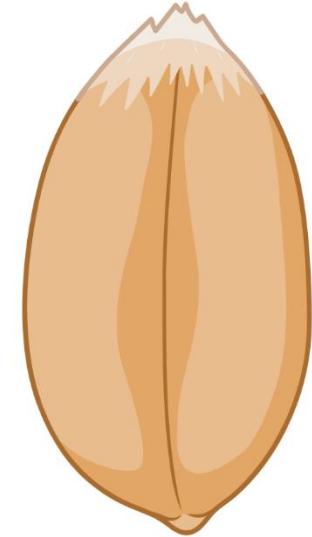
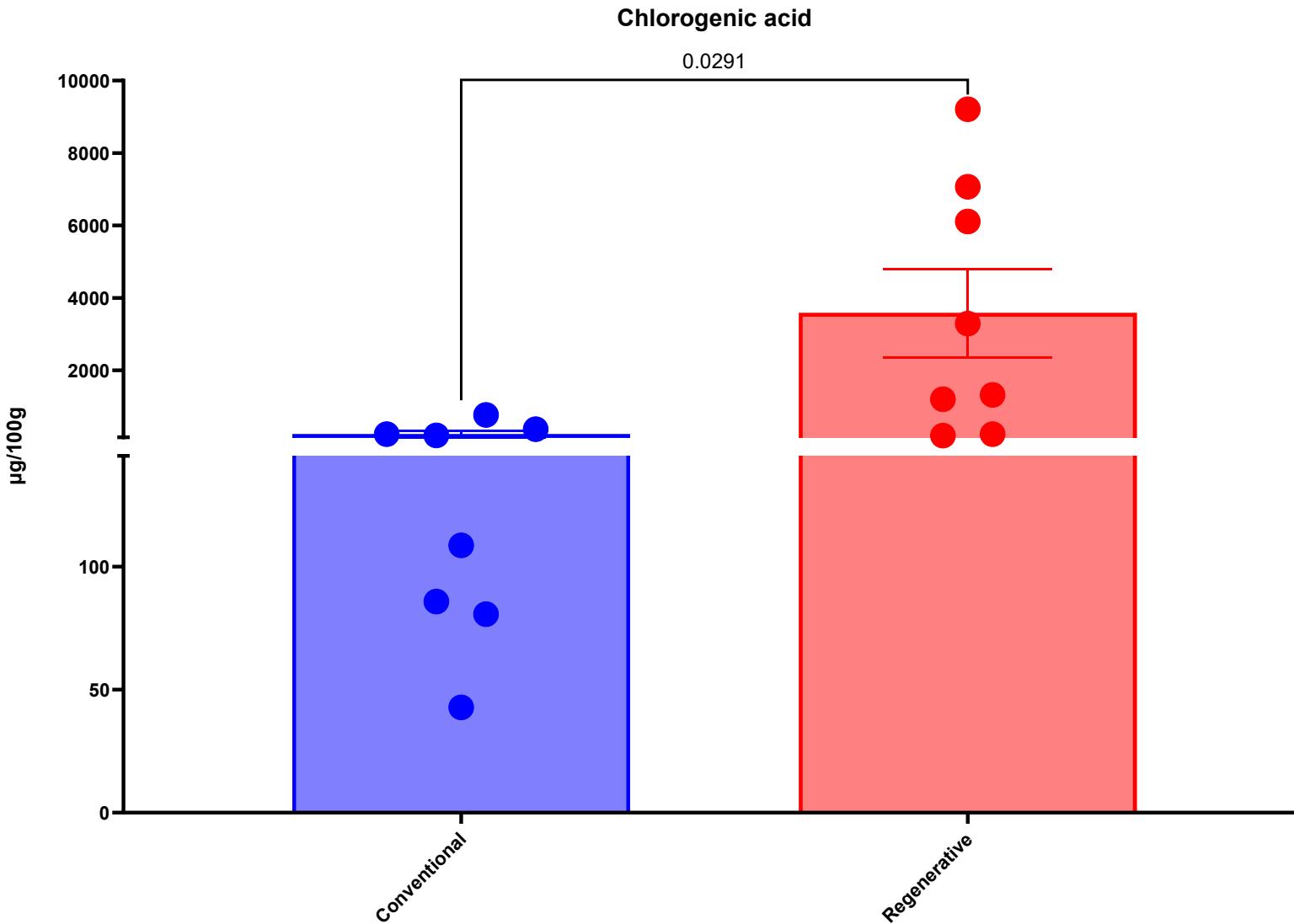
Two paired fields of wheat grown in California (collab with Chico State)



Conventional: monoculture with synthetic fertilizer and pesticide application

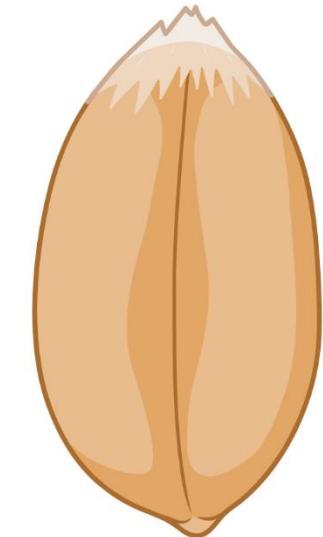
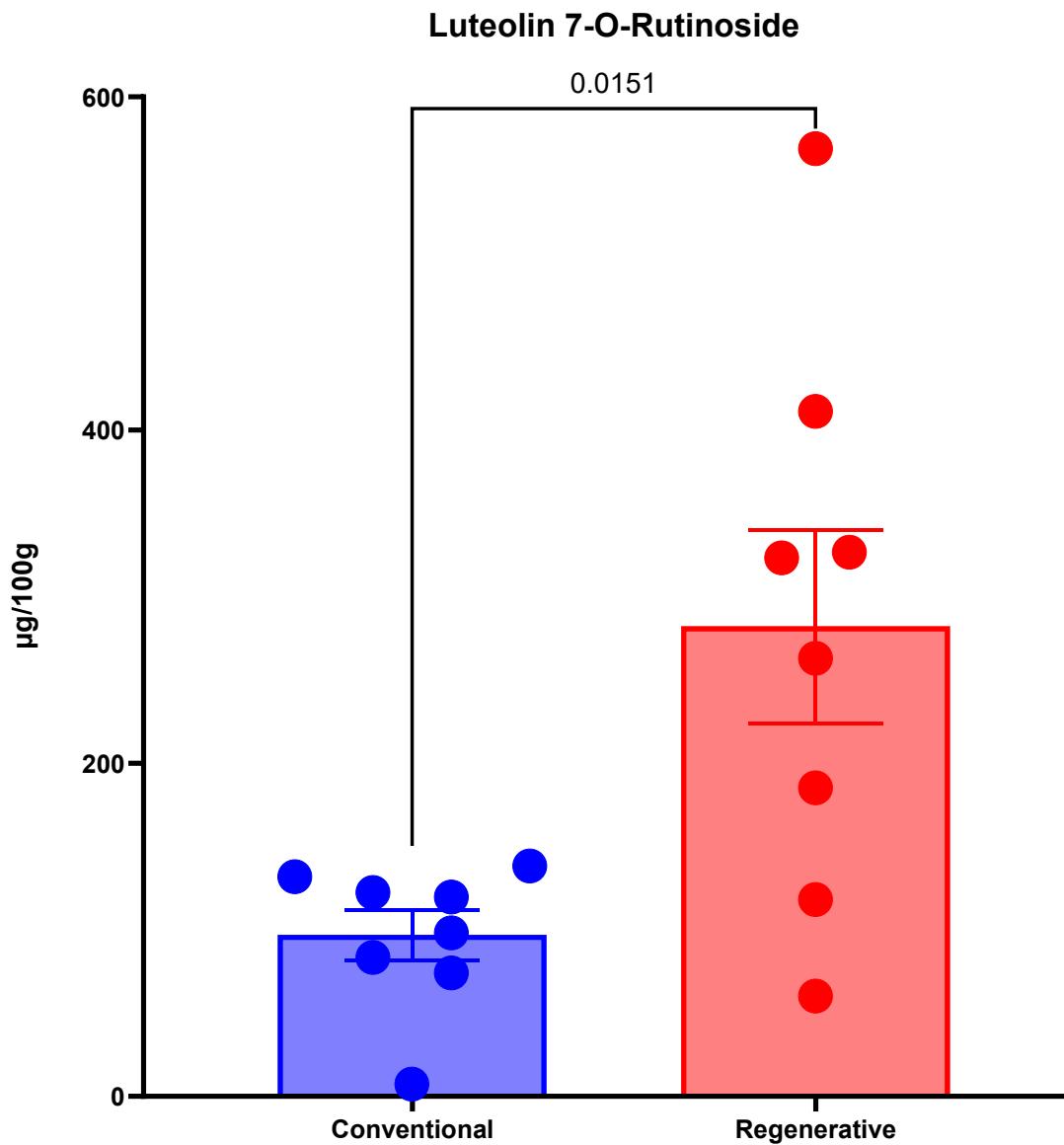
Regenerative: multi-species with organic fertilizer and inoculants

Phenolics in wheat

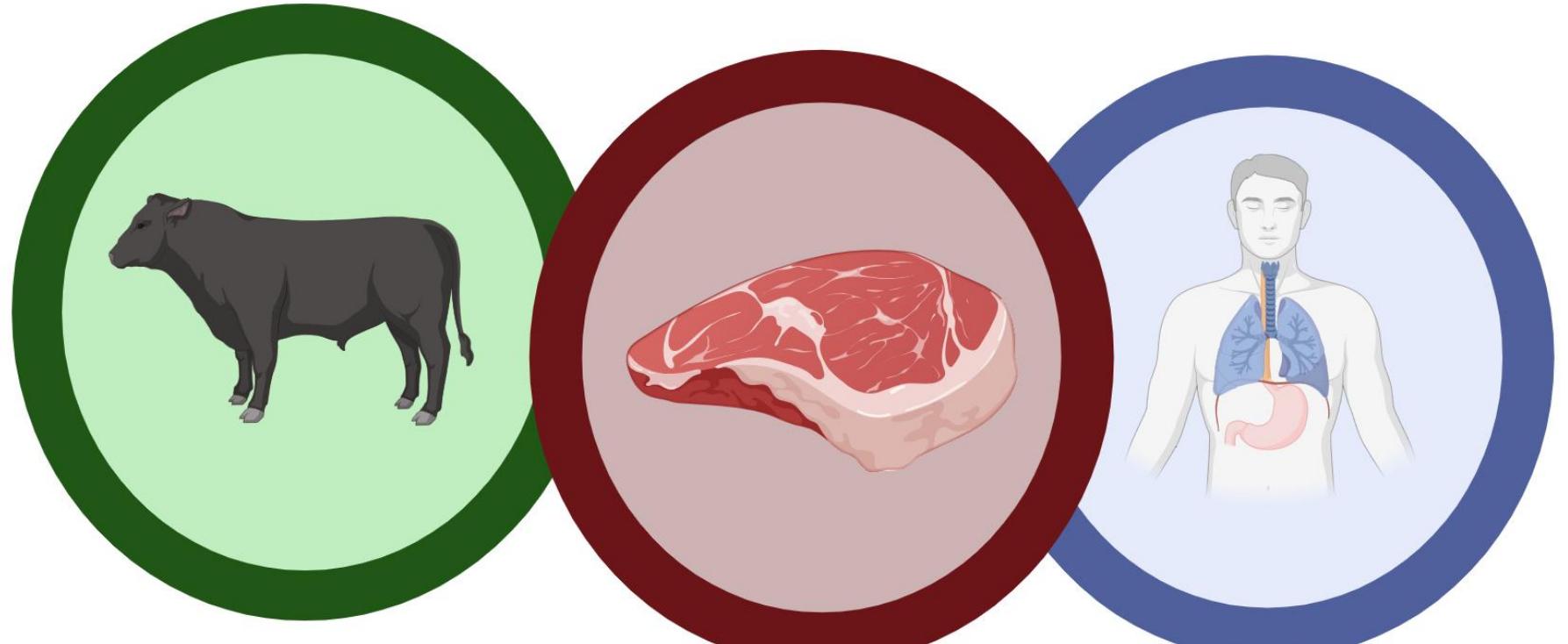


Typically, phytonutrients are increased because you have a “tougher” plant in regenerative systems. There is more interaction with its environment, and it interacts through secondary phytonutrient metabolism.

Phenolics in wheat

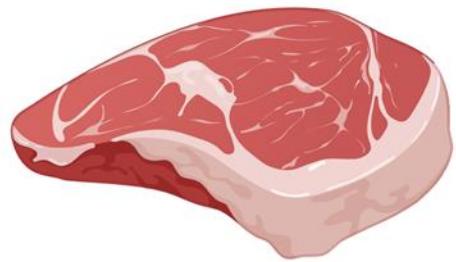


The impact of pastured vs conventional animal sourced food consumption on human health

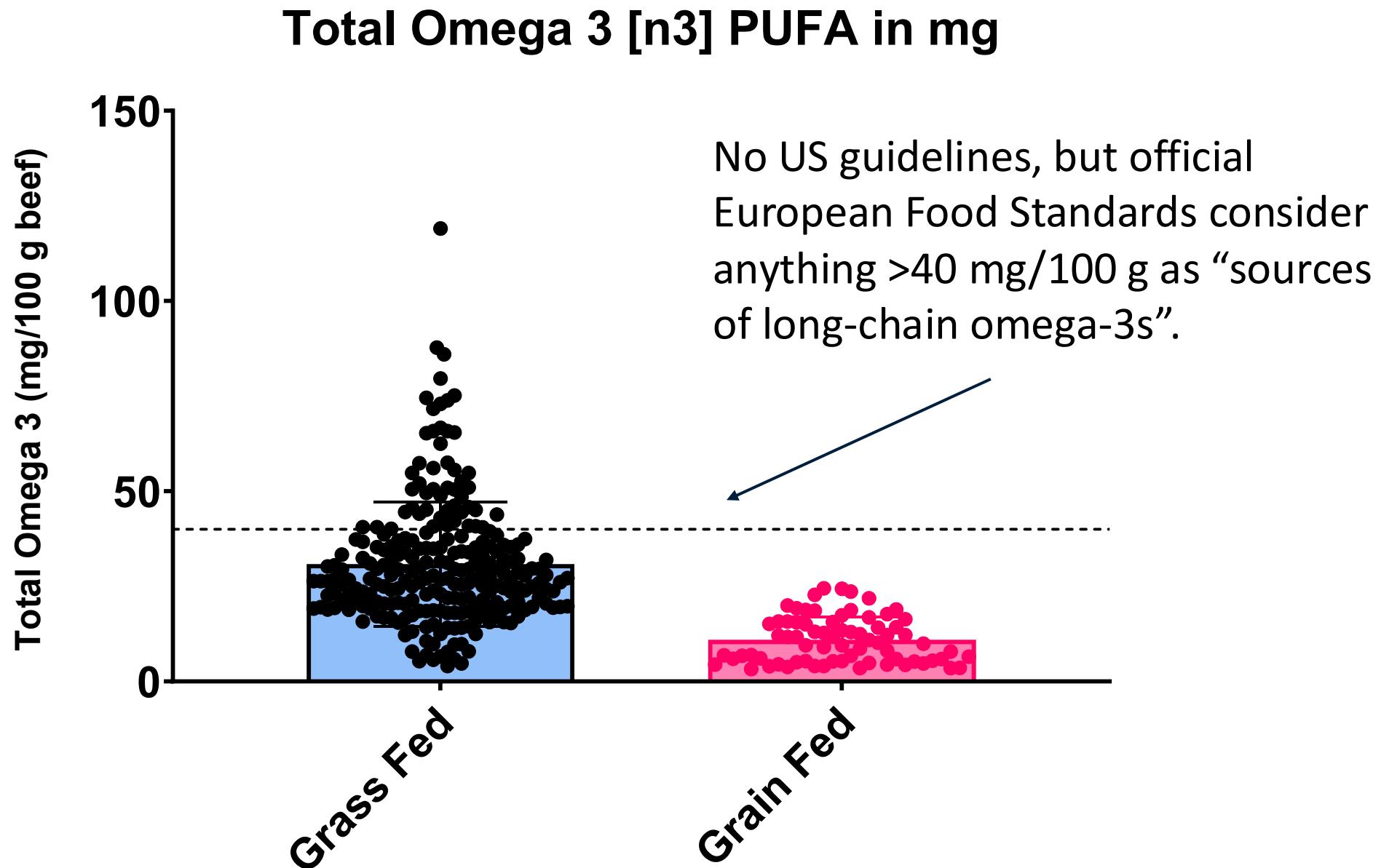


Linking animal and human health

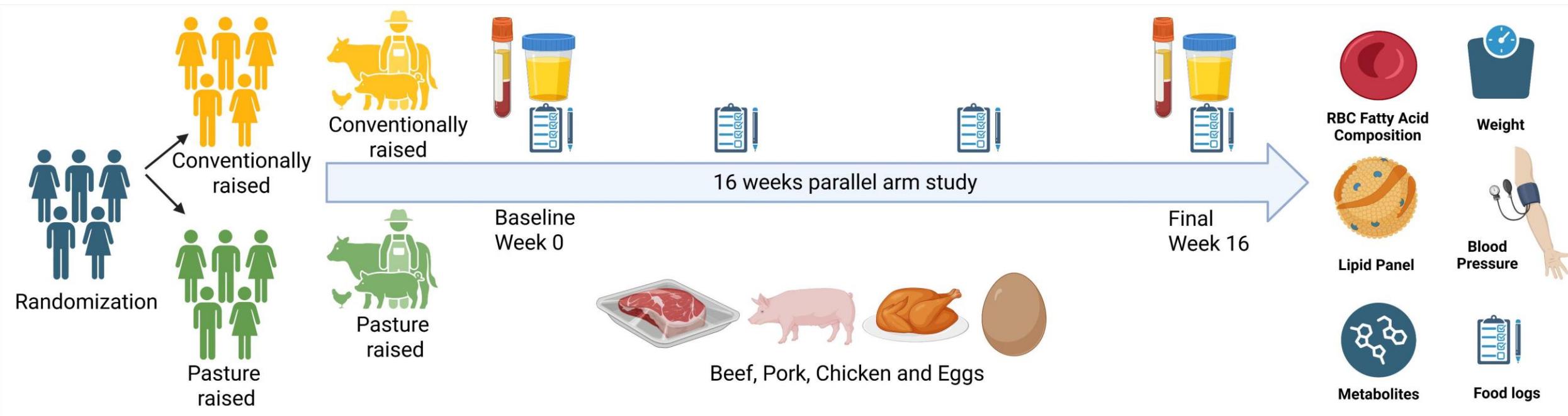
Is grass-fed beef a good source of omega-3 fatty acids?



Assuming an average ribeye fat content of 15 grams/100 grams



4-month RCT comparing pastured vs conventional animal sourced foods on human health



We completed the study completed in
October 2025

Average N 6:3 ratio in whole blood of Americans is about 9. Can we lower this with pastured meat and eggs?

Table 7 Distribution of *n*-3 levels (EPA + DHA), AA: EPA ratio, and total *n*-6:*n*-3 ratio in whole blood in countries from North- and South America (≥ 35 samples)

Country	<i>n</i>	Age	<i>n</i> -3 level (%)	AA: EPA ratio	Total <i>n</i> -6: <i>n</i> -3 ratio				
						Mean (SD)	Mean (SD)	Median (IQR)	Median (IQR)
North America									
Anguilla	51	39 (14.1)	3.7 (1.3)	13.2 (13.5)	5.8 (3.1)				
Mexico	534	48 (14.4)	3.0 (1.4)	20.8 (21.8)	8.0 (3.8)				
Canada	1600	50 (15.9)	2.9 (1.5)	15.1 (12.8)	7.6 (3.3)				
United States	13,867	49 (16.4)	2.7 (1.5)	22.3 (20.5)	9.0 (4.5)				
Guatemala	49	50 (15.8)	2.6 (1.0)	24.3 (18.8)	8.5 (3.8)				
South America									
Brazil	80	40 (15.2)	3.7 (1.4)	18.8 (19.9)	6.4 (2.9)				

Like in cows, a lower omega 6:3 ratio in our blood is associated with improvements in health

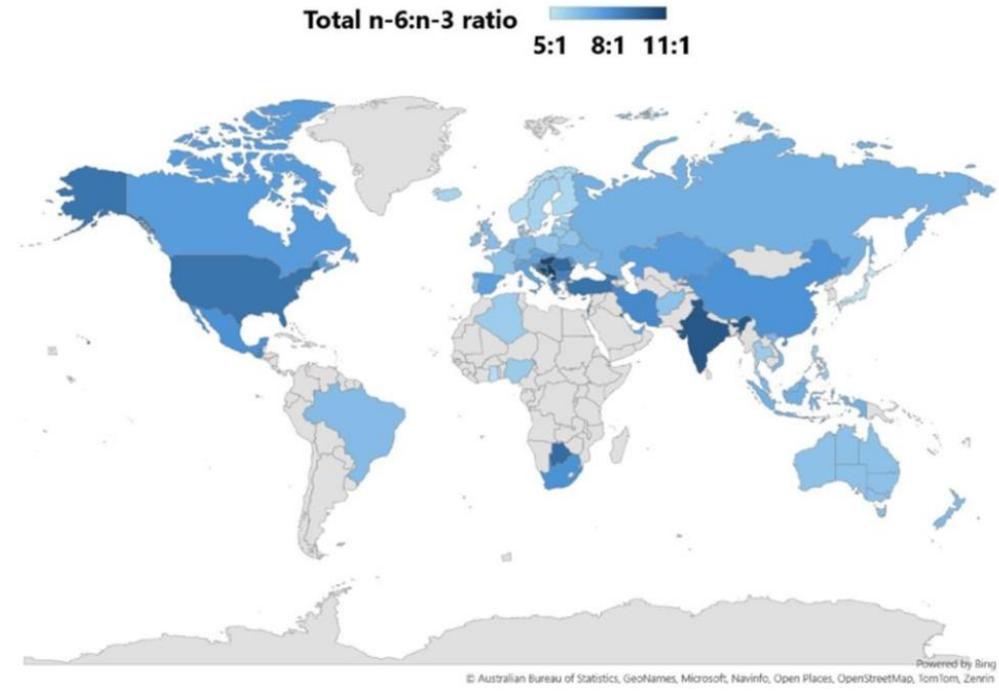


Fig. 2 Global distribution of total *n*-6:*n*-3 ratio in countries with ≥ 35 samples

- Torrissen M, Gisslevik E, Gundersen TE, Bolstad T, Eide O, Rizzo AM, Clayton P, Robertson C. ***Lipids in Health and Disease.*** 2025.

The pastured group dropped the omega 6:3 ratio in their blood to 2.5

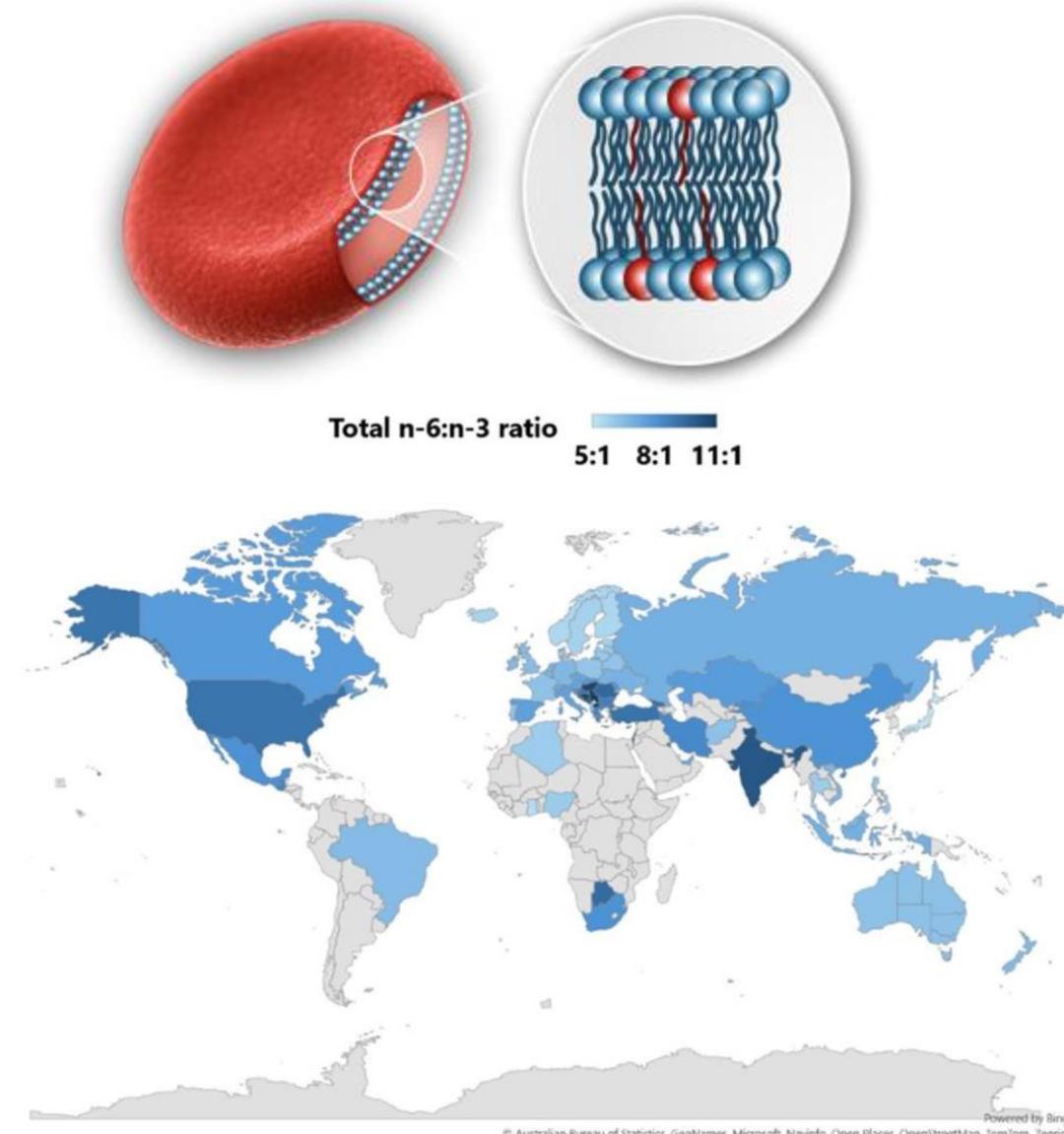
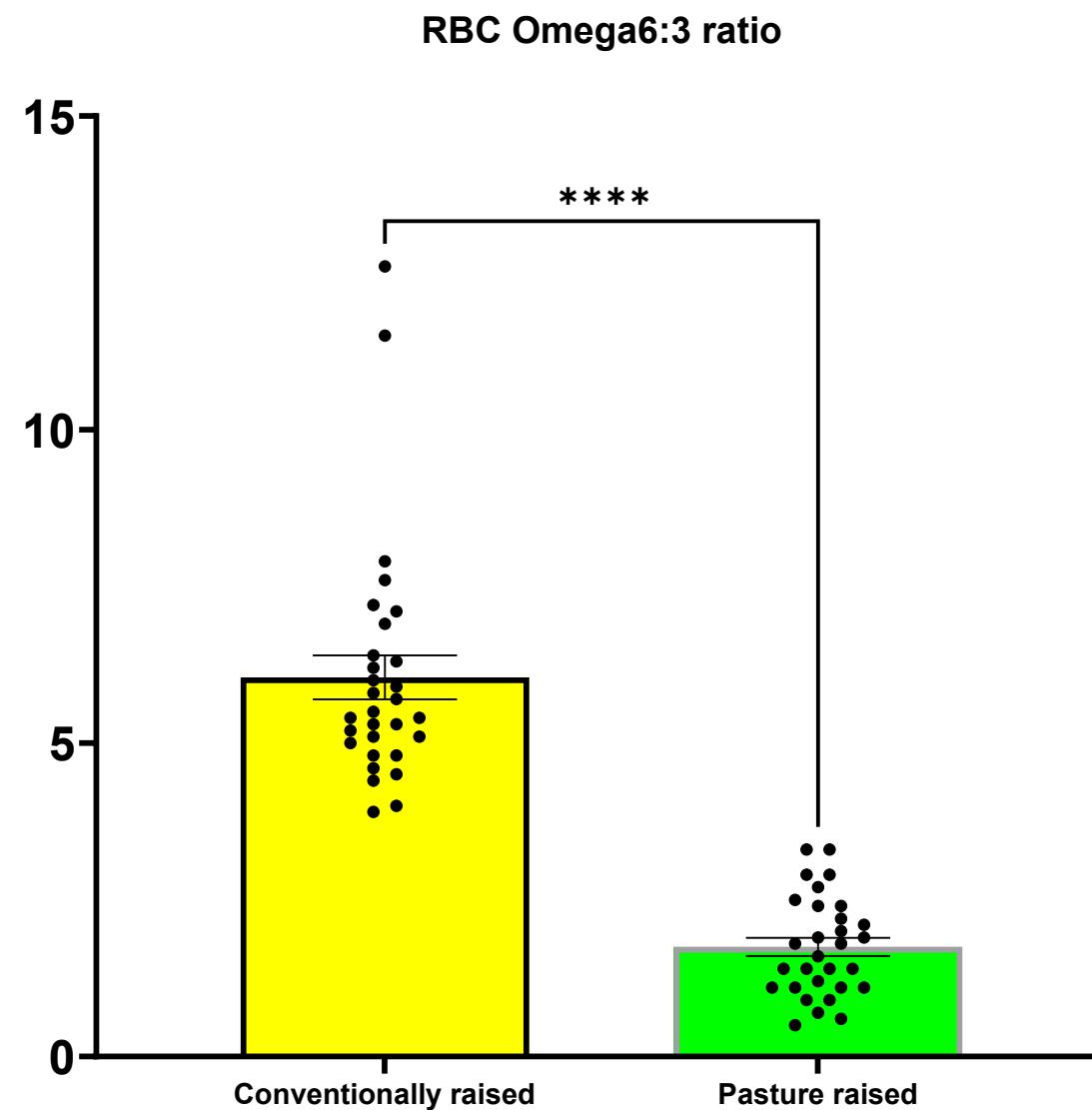
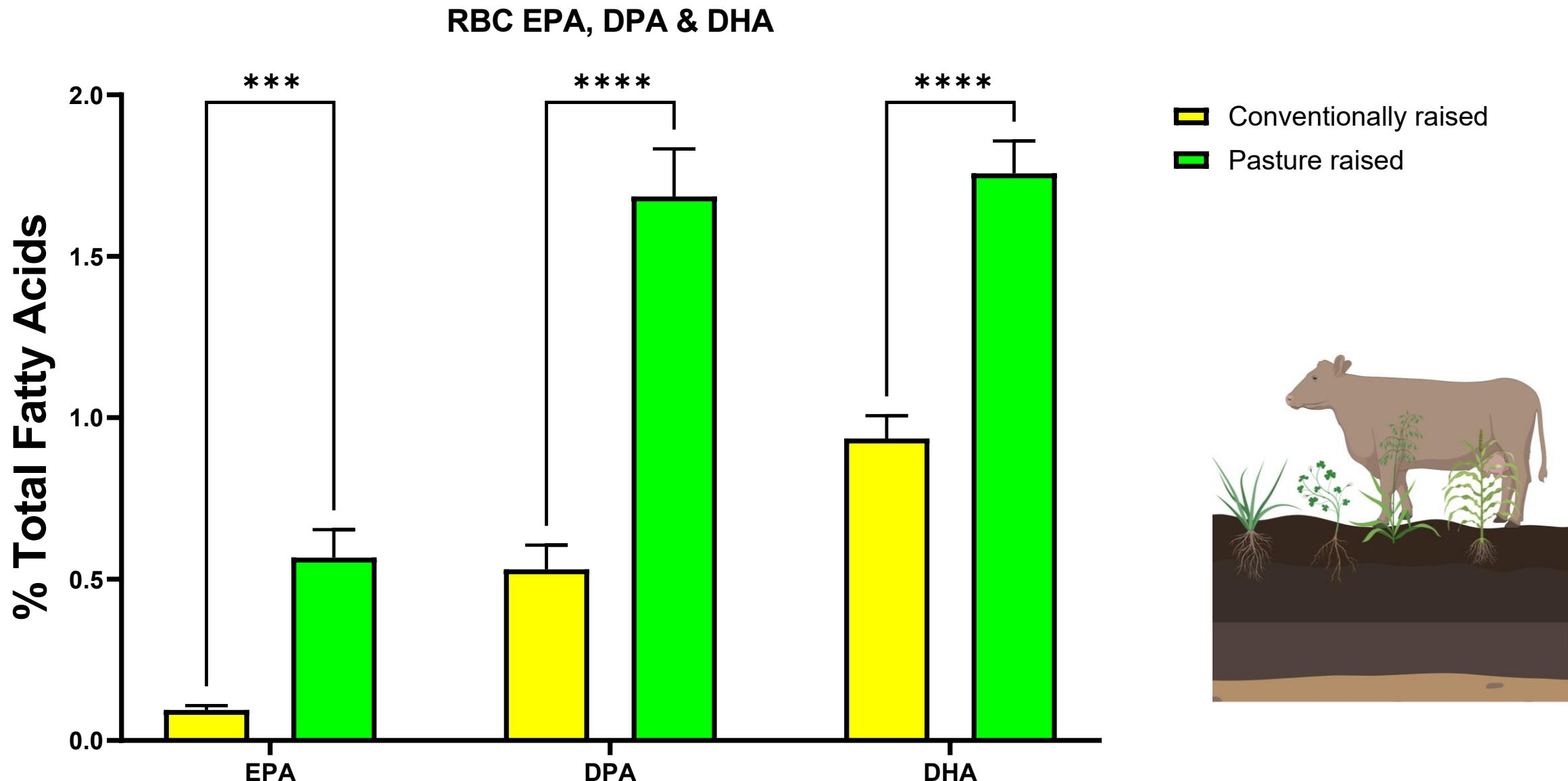


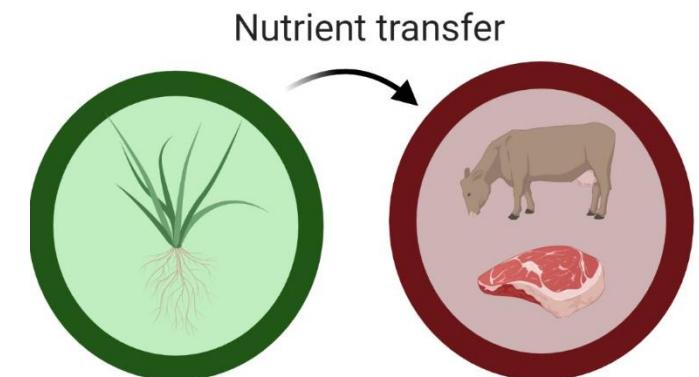
Fig. 2 Global distribution of total n-6:n-3 ratio in countries with ≥ 35 samples

All three very long-chain omega-3 FAs were increased in the blood



Conclusions and directions

- Phytonutrients—phenols, flavonoids, carotenoids, and other anti-oxidants—are a major class of nutrients that become enriched in foods.
- These have antioxidants, anti-inflammatory, and anti-microbial effects in livestock and humans.
- Also finding increased levels of omega-3 fatty acids in grass-fed beef with little differences in b-vitamins and more subtle differences in minerals.
- Omega-3s are increased in grass-fed beef on biodiverse pastures, which can raise omega-3 levels in the blood of people.
- Bigger picture: Diet quality is a main consideration, eating pastured meat/milk or “regenerative” grains as part of a Standard American Diet is unlikely to make a difference. But as part of a healthy diet rich in whole foods, it may be an important piece of the puzzle!





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Thank you!

Questions and Discussions

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For our research papers and nutrient density testing capabilities:

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