

“Novel” methods to determine meat provenance

Frank Monahan



Food Provenance

Geographical
origin

- “the **place of origin or earliest known history** of something the beginning of something's existence”

“Traceability” - the ability to follow the movement of a food through specified stages of production, processing and distribution

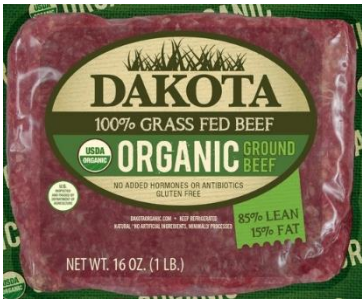
- “a **record of ownership** ... used as a guide to **authenticity** or quality”

“Authenticity” - the process by which food is verified as complying with its intended description

Food
Fraud

BURGUNDY Pasture Beef
 100% Grass Fed. Sustainable. Wholesome.

Gourmet pasture beef



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Grass-Fed Beef from Australia

Australia is famous for its sustainable farming methods and quality grass-fed beef. Deep in the Australian Outback, passionate farmers raise free range cattle in spacious grasslands. Afforded up to 10 acres per head, cattle range freely within rotational feeding systems, optimizing the long-term sustainability of the land.



IOFGA Licence No: 1039 Organic Certification IRL-01B2-EU Certified Organic

Approved Organic Standard IOFGA

Potential tracers of **production system**

- Fatty acids
- Volatiles, terpenes, aldehydes
- Carotenoids
- Vitamin E
- Gene expression
- Fingerprinting (non-targeted methods)



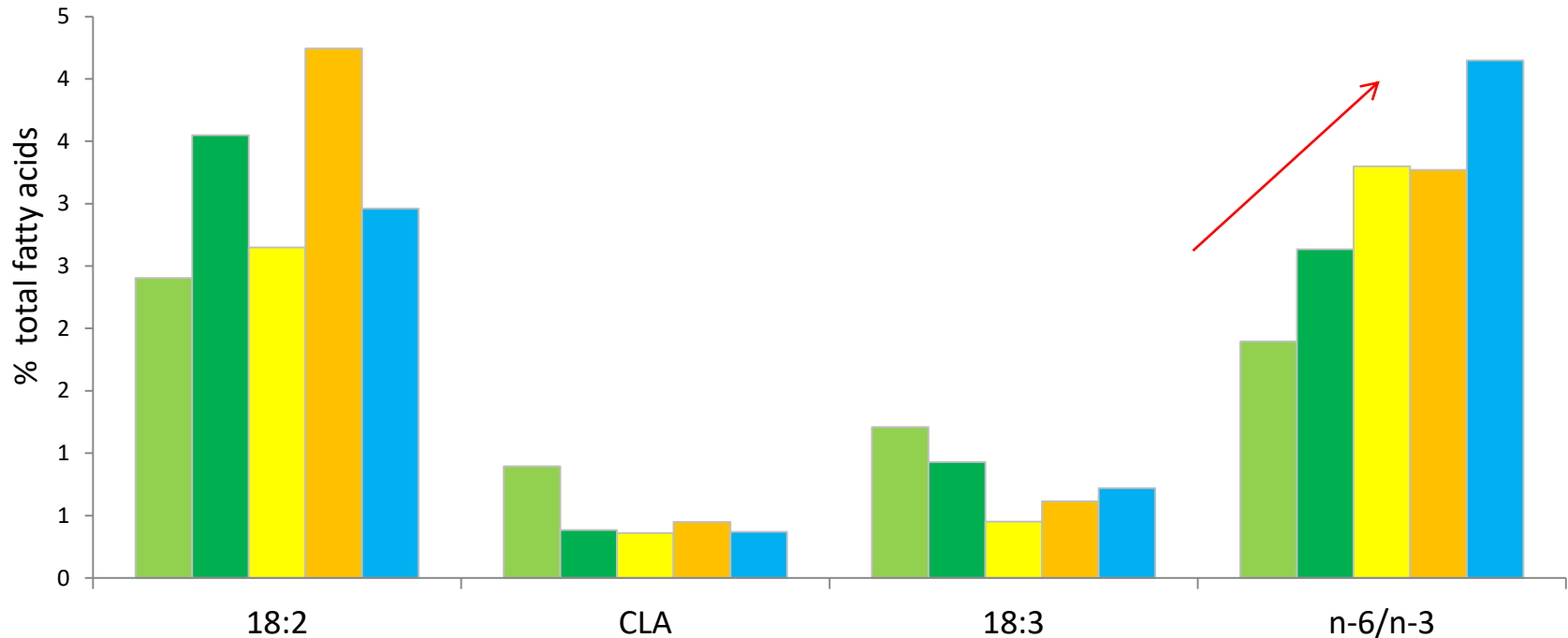
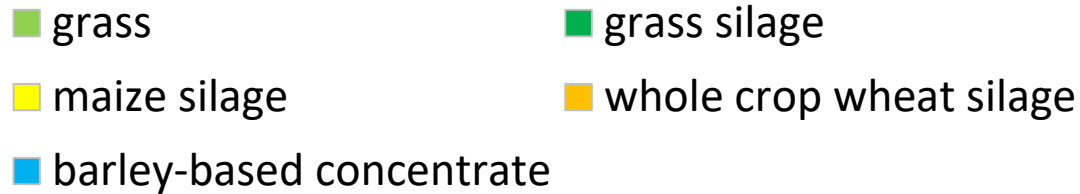
.....and **geographical origin**

- Stable isotopes
- Trace elements

Methods

- GC/HPLC analysis of fatty acids, terpenes, phenolics, carotenoids, vitamin E
- Molecular techniques – DNA-based, gene expression
- Spectroscopic (“fingerprint”) techniques: visible, IR, UV, fluorescence, Raman
- Isotope ratio mass spectrometry (IRMS) analysis of stable isotopes
- Trace element analysis (ICP-MS)

Fatty acids in beef

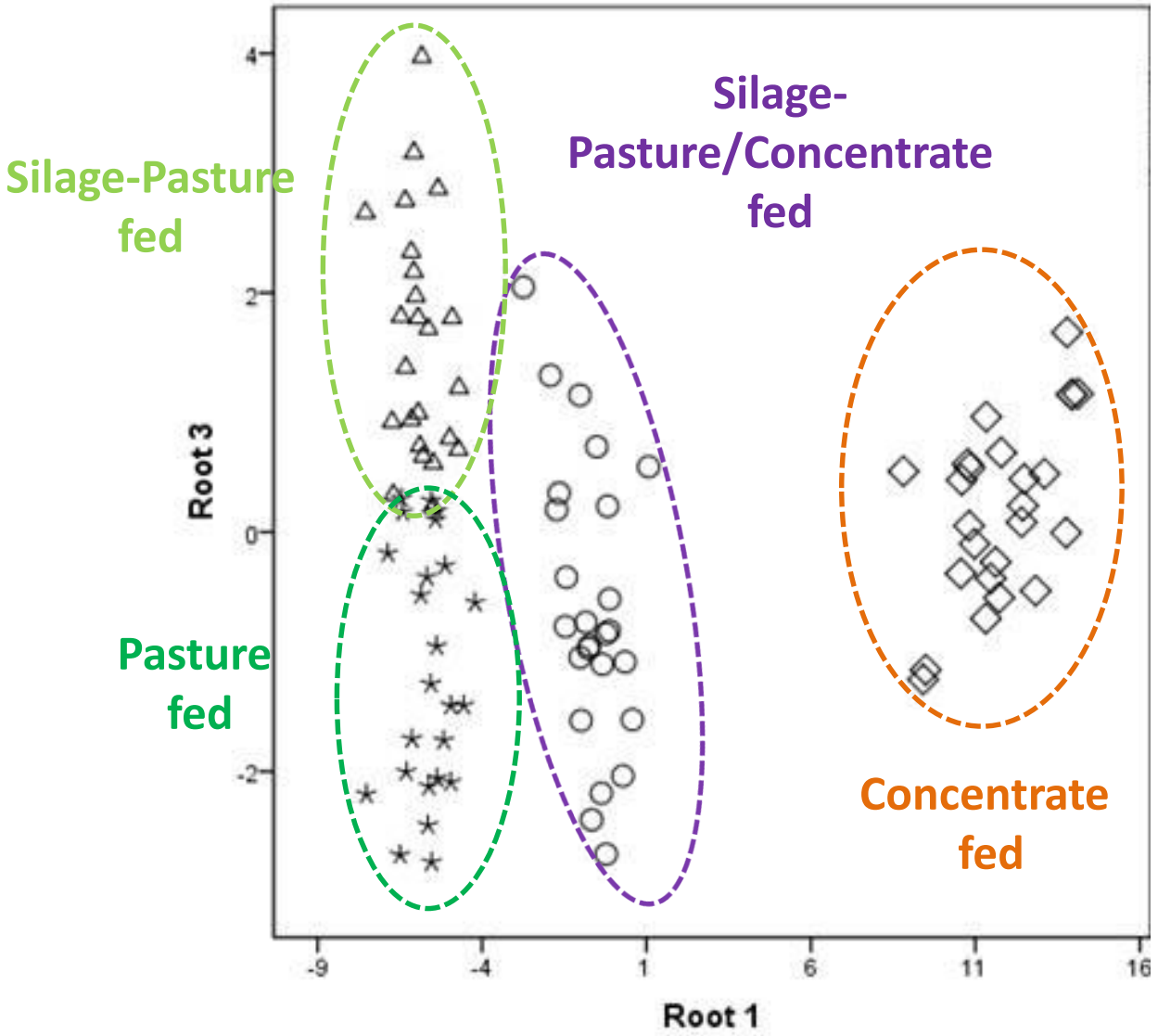


French et al, 2000, J. Anim. Sci., 78, 2849
Moloney et al, 2013, Meat Sci., 95, 608
Noci et al, 2005, J. Anim. Sci., 83, 1167

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28/2-1/3, 2019



Canonical discriminant analysis



REIMS (rapid evaporative ionization mass spectrometry)



<http://videos.waters.com/detail/videos/mass-spectrometry/video/4285321196001/reims-research-system---how-it-works>

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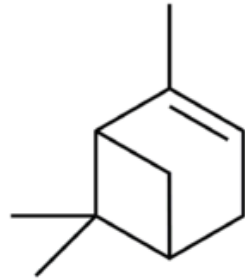


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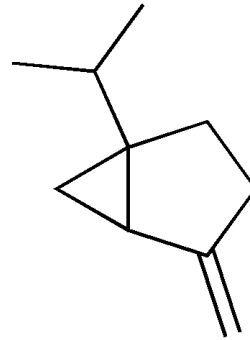
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Volatiles - terpenes

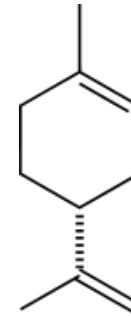
Monoterpenes:



pinene

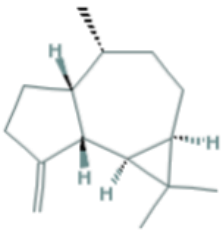


sabinene

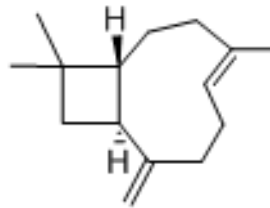


limonene

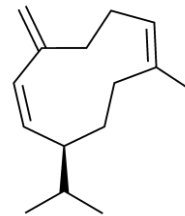
Sesquiterpenes:



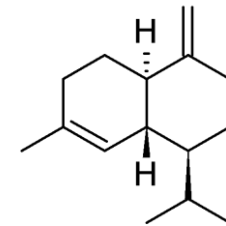
β -gurjunene



β -caryophyllene

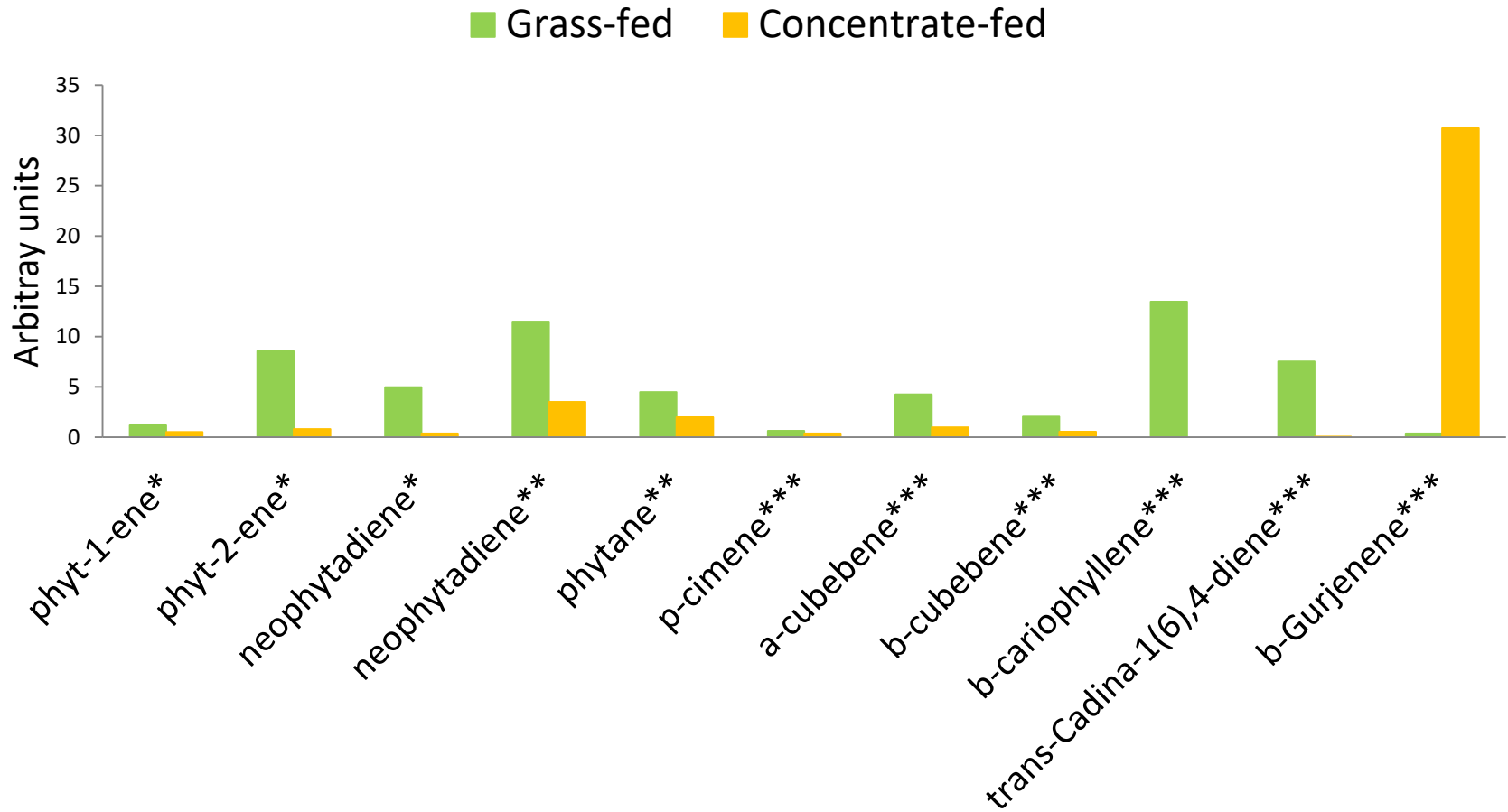
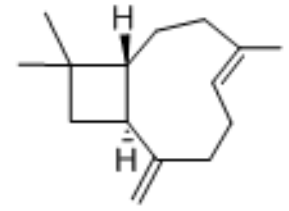


germacrene



γ -cadinene

Terpenes in sheep fat

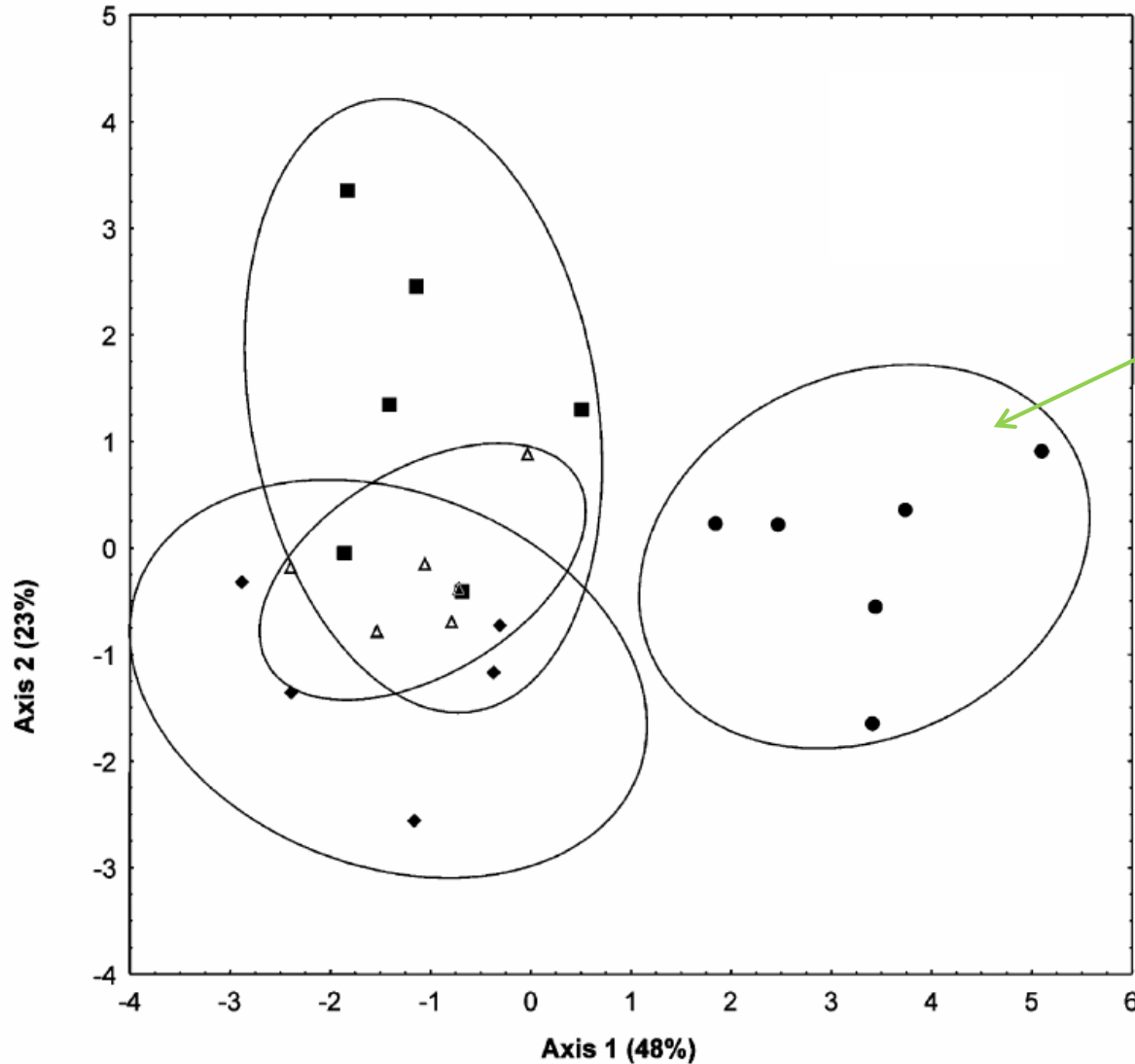


*Suzuky & Bailey, 1985, JAFc, 33, 343

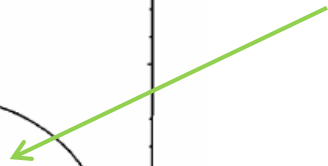
**Young et al., 1997, Meat Sci., 45, 183

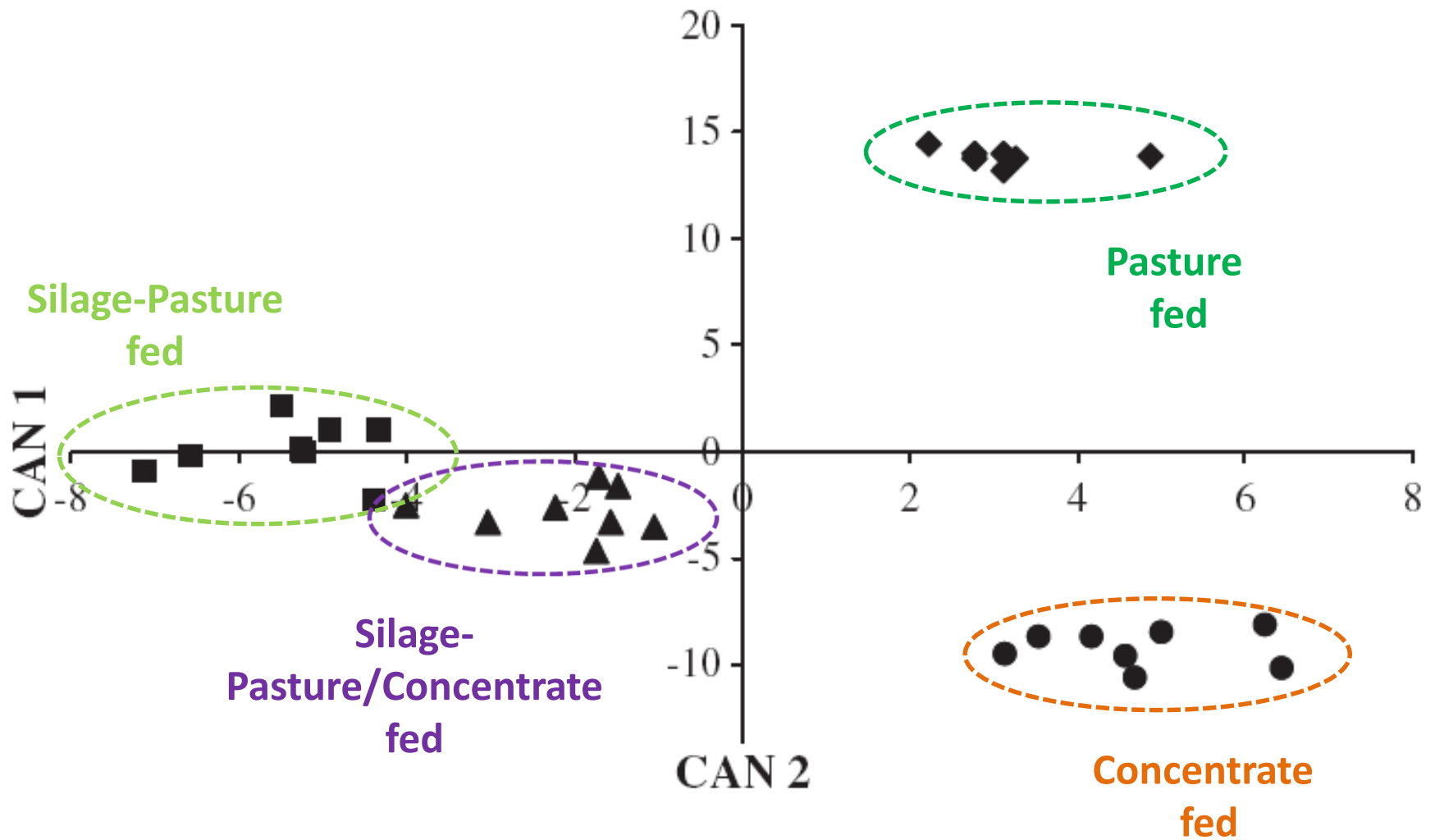
***Priolo et al., 2004, Meat Sci., 66, 475

Factorial discriminant analysis using four terpenes to discriminate lamb



Pasture-fed
lamb





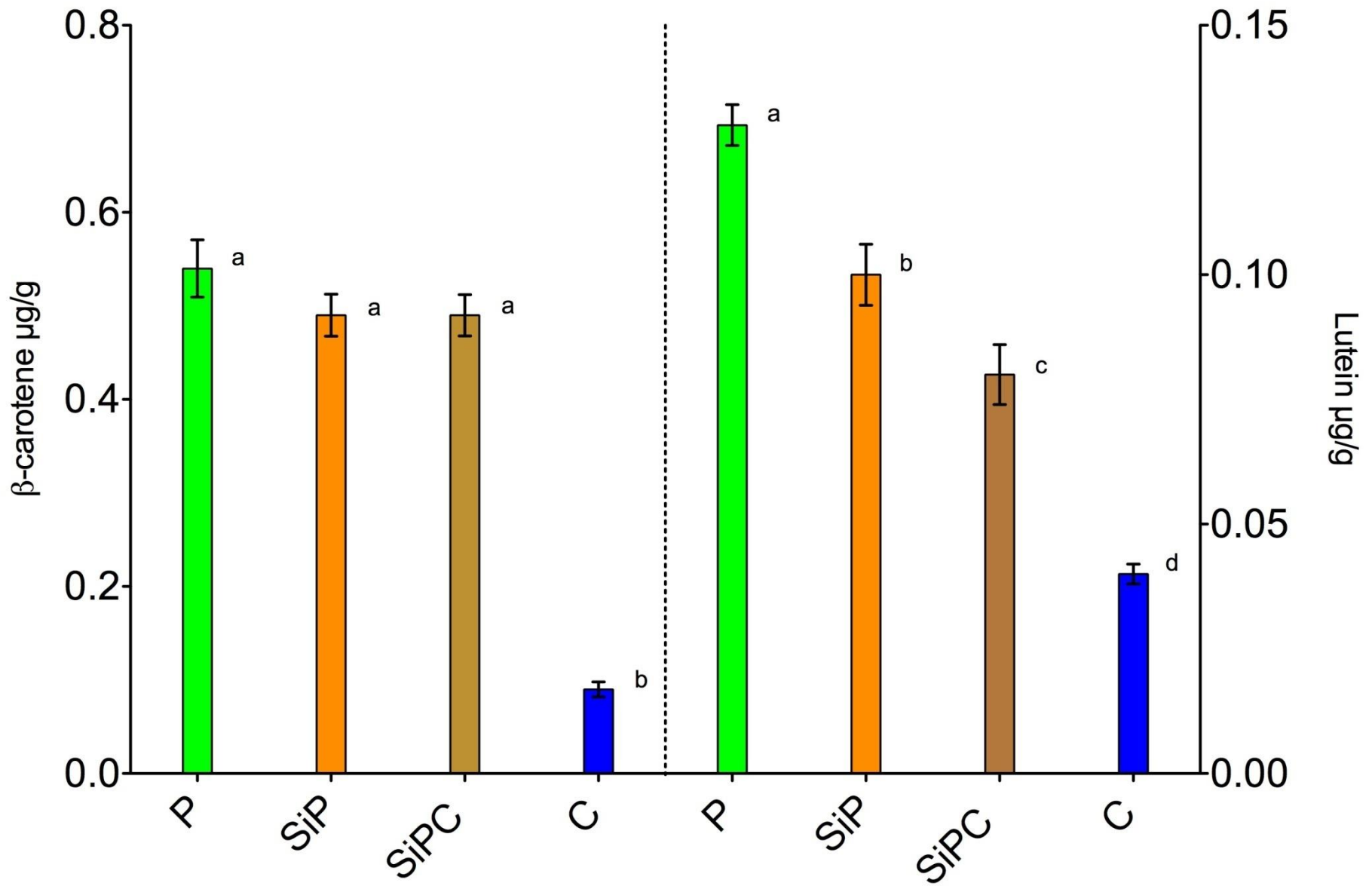
Potential tracers of production system

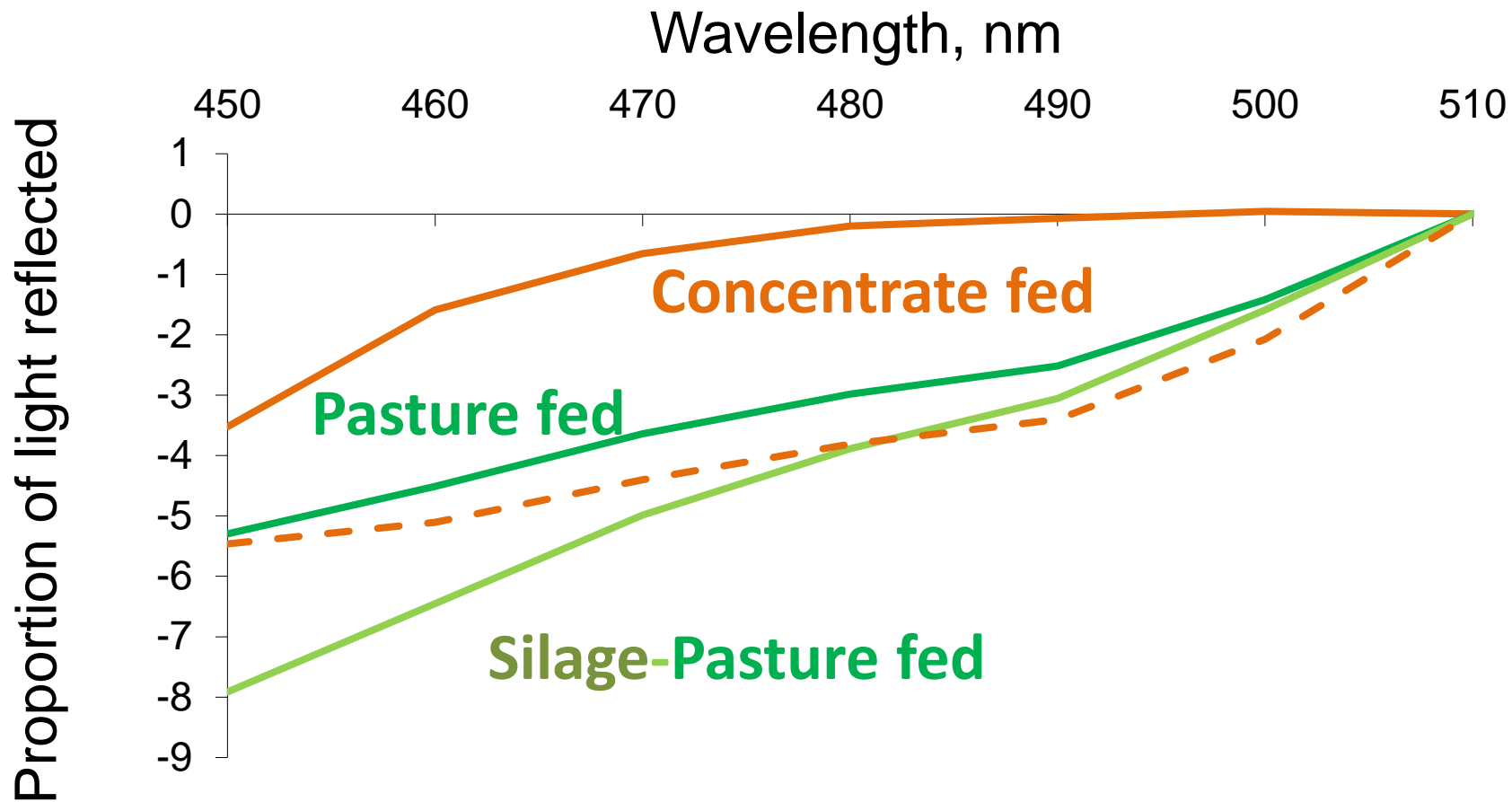
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- **Carotenoids**
- Vitamin E
- Gene expression
- Fingerprinting (non-targeted methods)



.....and geographical origin

- Stable isotopes
- Trace elements





Röhrle et al.
 (2011). Meat Sci.
 88, 347-53

Frank Monahan, UCD, AIMSNI, Belfast,
 28/2-1/3, 2019



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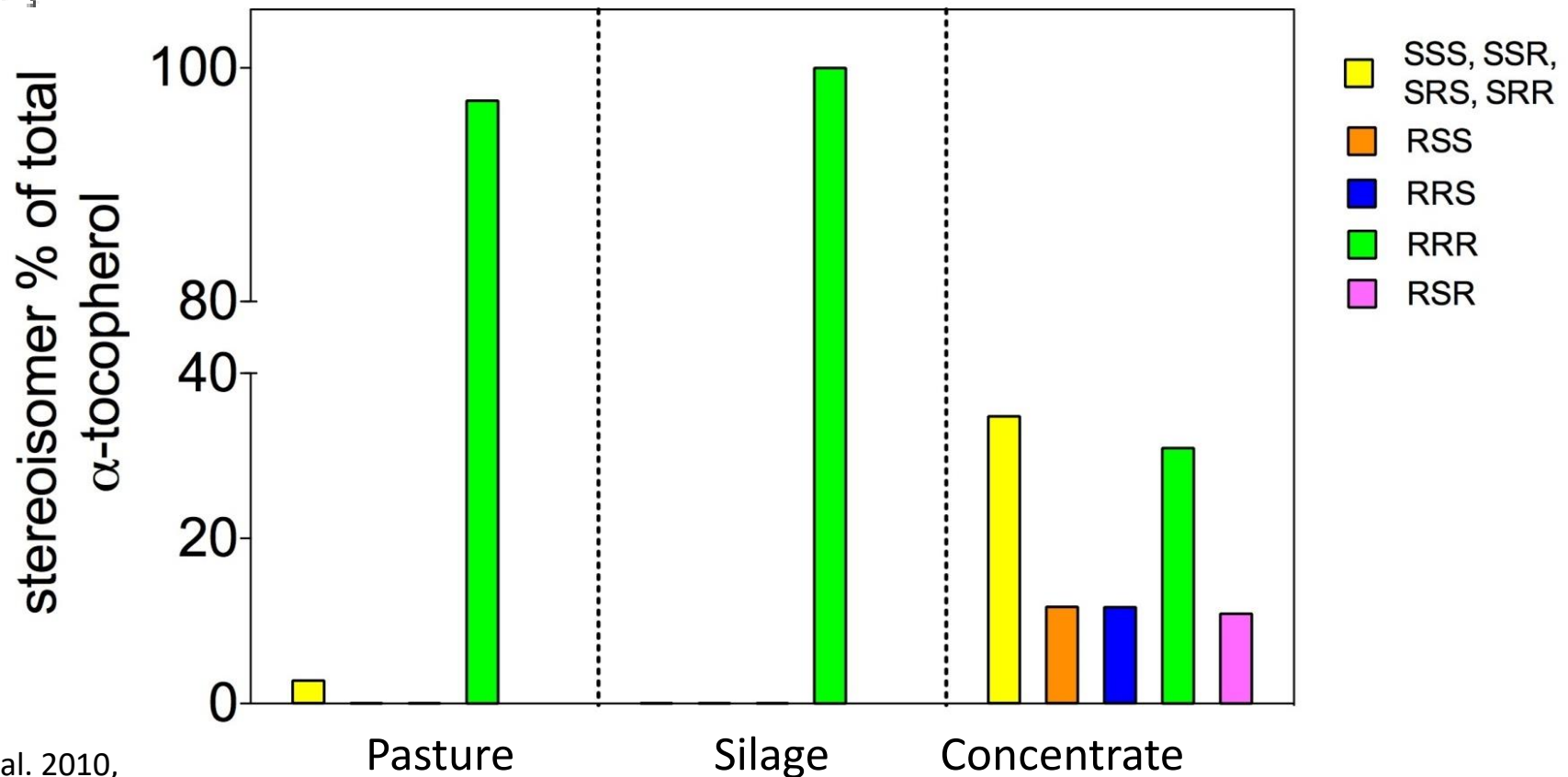
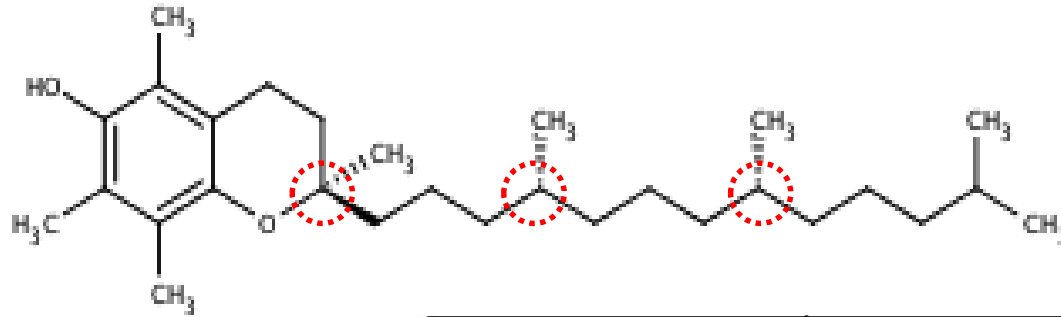
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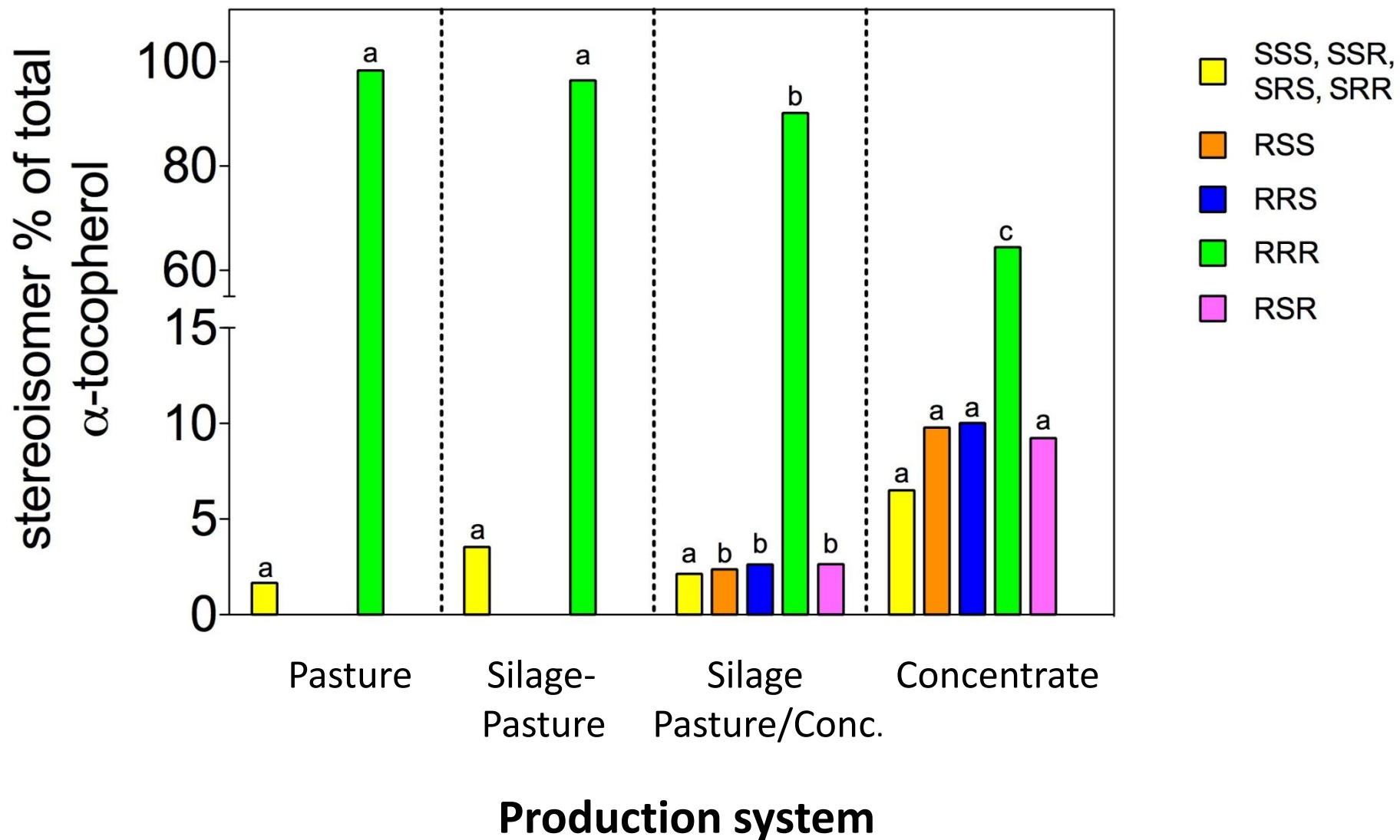


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Vitamin E stereoisomers in animal feeds





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Genetic markers?

Authors

Genes

Cassar-Malek et al.
(2009)

Selenoprotein W up-regulated in outdoor pasture vs indoor concentrate

Duckett et al. (2009)

Stearoyl CoA desat and **FAS** up-regulated in concentrate finished vs pasture

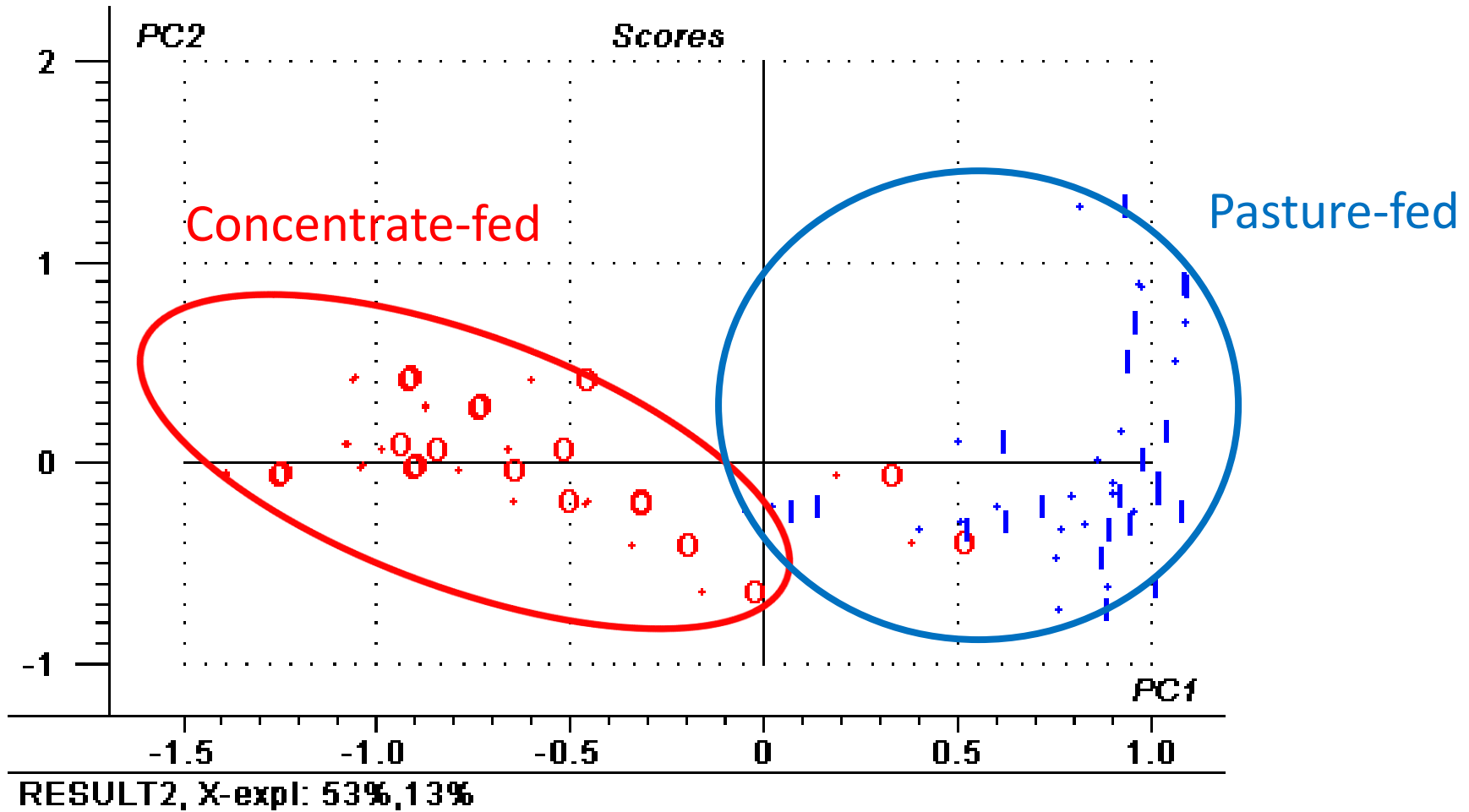
Shibato et al. (2009)

Differential expression attributed to changes in fibre type and metabolic enzymes

Lejeune et al (2015)

21 genes differentially expressed in outdoor pasture vs indoor concentrate-fed beef cattle

PCA – gene expression data



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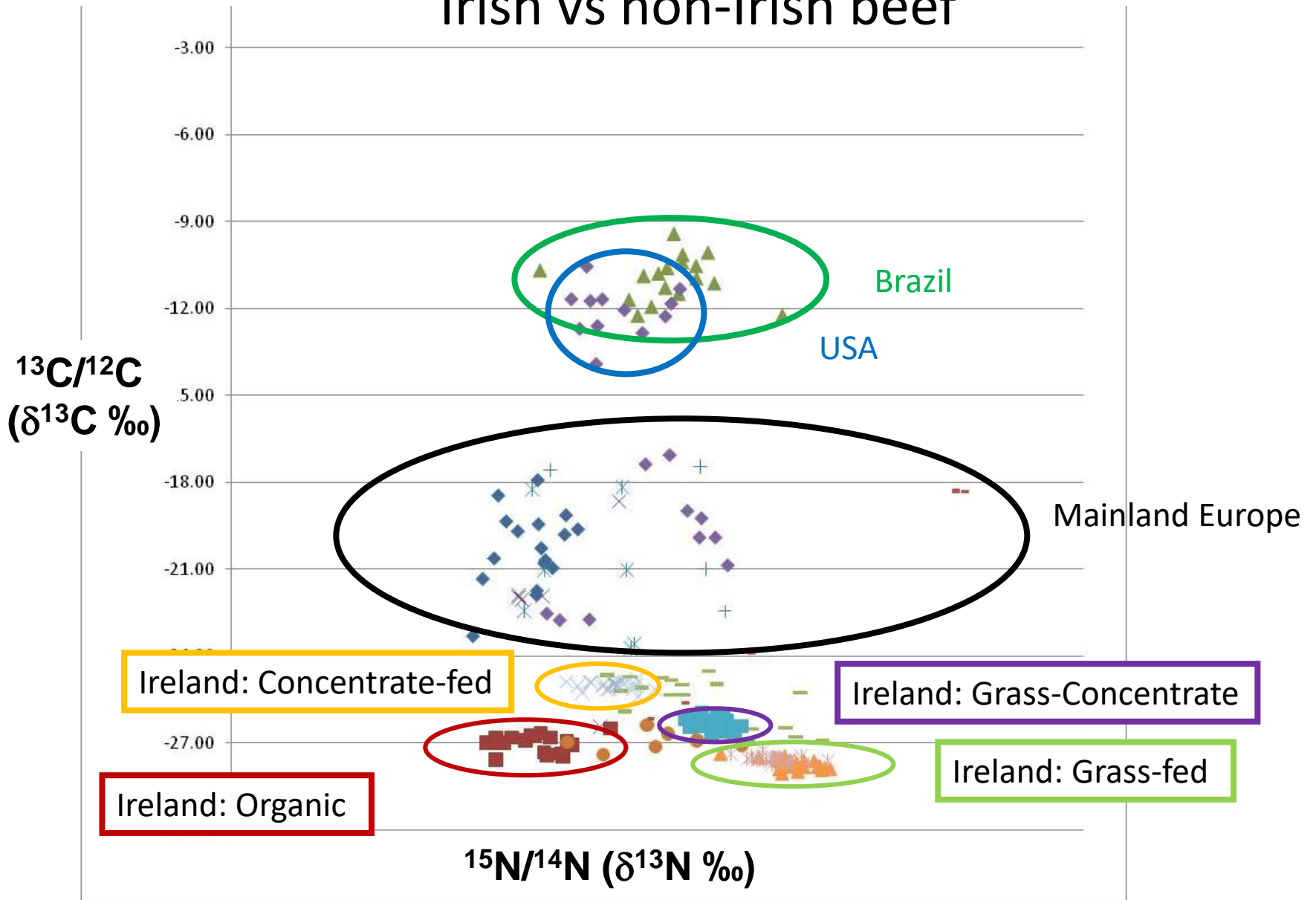
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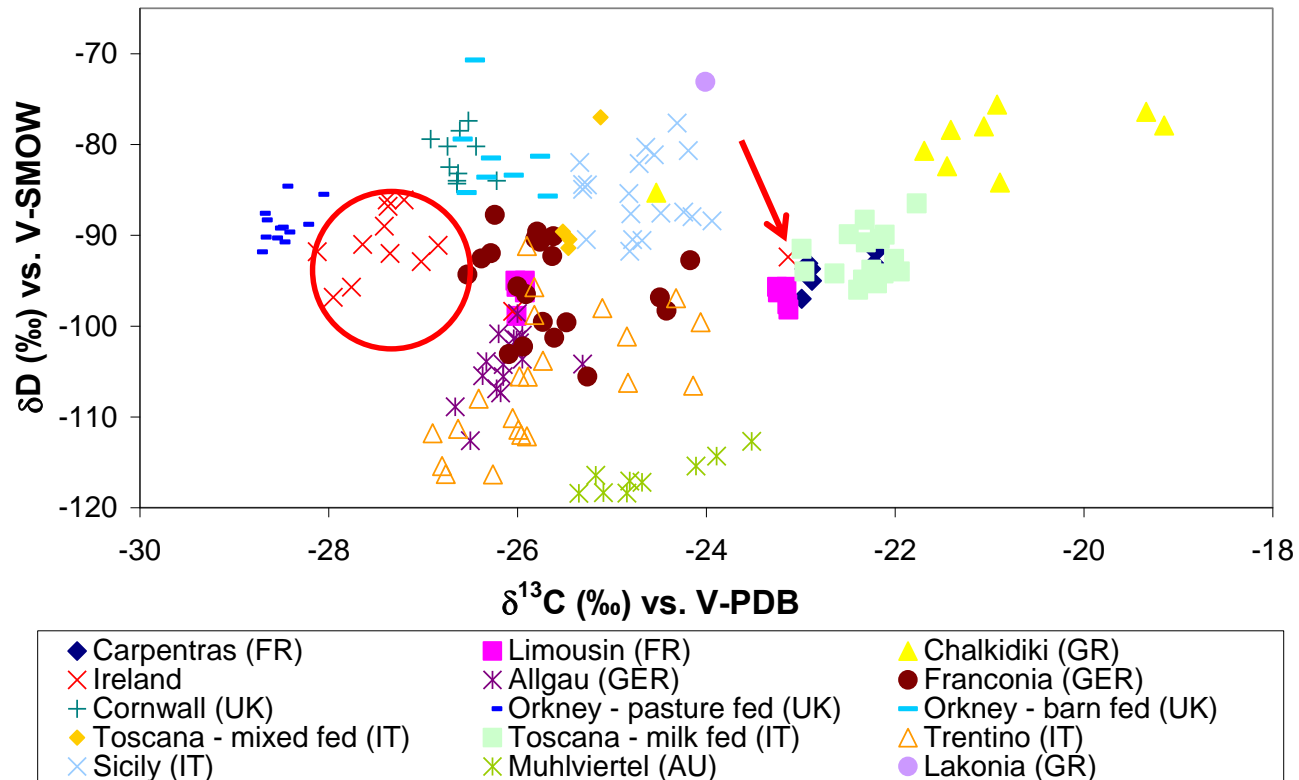
Irish vs non-Irish beef



Geographical origin of beef ($^2\text{H}/^1\text{H}$, $^{13}\text{C}/^{12}\text{C}$, $^{15}\text{N}/^{14}\text{N}$, $^{34}\text{S}/^{32}\text{S}$)

country	predicted group membership									total
	AU	BR	FR	GE	IR	IT	SP	UK	US	
AU	6	0	0	0	0	0	0	0	0	6
BR	0	17	0	0	0	0	0	0	0	17
FR	1	0	1	0	0	1	1	0	0	4
GE	2	0	0	3	1	0	0	0	0	6
IR	0	0	0	0	42	0	0	4	0	46
IT	0	0	0	0	0	16	2	0	0	18
SP	1	0	0	0	2	0	4	0	0	7
UK	0	0	0	0	3	0	0	17	0	20
US	1	0	0	0	0	3	0	0	18	22
AU	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
BR	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
FR	25.0	0.0	25.0	0.0	0.0	25.0	25.0	0.0	0.0	100.0
GE	33.3	0.0	0.0	50.0	16.7	0.0	0.0	0.0	0.0	100.0
IR	0.0	0.0	0.0	0.0	91.3	0.0	0.0	8.7	0.0	100.0
IT	0.0	0.0	0.0	0.0	0.0	88.9	11.1	0.0	0.0	100.0
SP	14.3	0.0	0.0	0.0	28.6	0.0	57.1	0.0	0.0	100.0
UK	0.0	0.0	0.0	0.0	15.0	0.0	0.0	85.0	0.0	100.0
US	4.5	0.0	0.0	0.0	0.0	13.6	0.0	0.0	81.8	100.0

European Lamb



Camin et al. (2007) Analytical and Bioanalytical Chemistry, 389, 309.

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Elemental analysis in poultry breast (n=56)

^{75}As ($\mu\text{g}/\text{kg}$)	p^a	Brazil ($n = 10$)	France ($n = 11$)	Germany ($n = 12$)	Hungary ($n = 10$)	Switzerland ($n = 13$)					
^{23}Na (mg/kg)	**	5.81 ab	1.96	5.11 b	1.85	4.62 b	1.09	10.68 a	8.99	6.18 ab	2.12
^{85}Rb (mg/kg)	**	125 ab	21	125 b	23	145 ab	18	133 ab	23	154 a	28
^{77}Se ($\mu\text{g}/\text{kg}$)	***	12.2 b	2.4	8.0 a	2.5	7.3 a	1.2	8.8 a	1.5	7.6 a	2.1
^{88}Sr ($\mu\text{g}/\text{kg}$)	***	109 b	34	130 ab	22	121 b	20	158 a	31	160 a	30
^{205}Tl ($\mu\text{g}/\text{kg}$)	***	60.1 c	33.7	20.5 a	5.3	45.1 bc	20.7	31.7 ab	14.1	23.1 ab	10.6
^{75}As ($\mu\text{g}/\text{kg}$)	***	1.31 a	0.48	4.16 b	3.87	4.77 b	1.42	1.51 a	0.97	1.39 a	1.02

Classification using As, Na, Rb, Tl, Se, Sr

Actual origin	Predicted origin					
	Brazil	France	Germany	Hungary	Switzerland	% Correct
Brazil	10	0	0	0	0	100 
France	0	7	3	1	0	64
Germany	0	1	10	0	1	83
Hungary	1	2	0	6	1	60
Switzerland	1	1	0	1	10	77
Overall	12	11	13	8	12	77 

Franke et al. (2008). Eur Food Res.Tech. 227,701-708.





Classification using $\delta^{13}\text{C}$, $\delta^{15}\text{N}$, Mg, K, Mn, Zn, Se, and Zr

		predicted group membership ^a				
		Shandong	Heilong-jiang	Yunnan	Tibet	total
original	count	16				16
	Shandong		14			14
	Heilongjiang			15		15
	Yunnan				24	24
	Tibet	100	100	100	100	100
%						
cross-validated	count	16				16
	Shandong		14			14
	Heilongjiang			15		15
	Yunnan				24	24
	Tibet	100	100	100	100	100
%						

Zhao et al. 2013 J Agric Fd Chem. 61,7075.



Potential tracers of production system

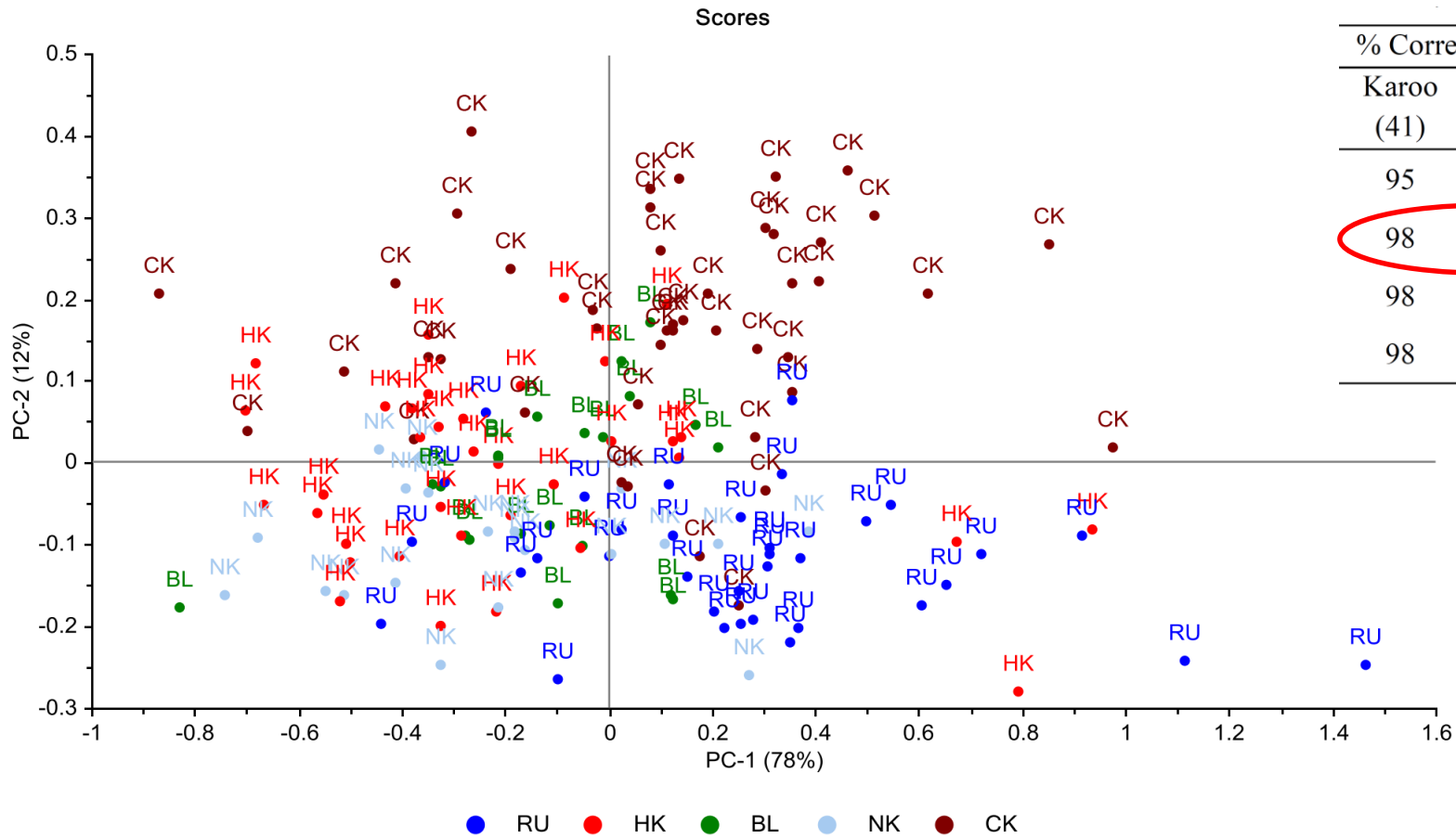
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- **Fingerprinting (non-targeted methods)**

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% Correct	
Karoo (41)	Non-Karoo (12)
95	67
98	83
98	67
98	83

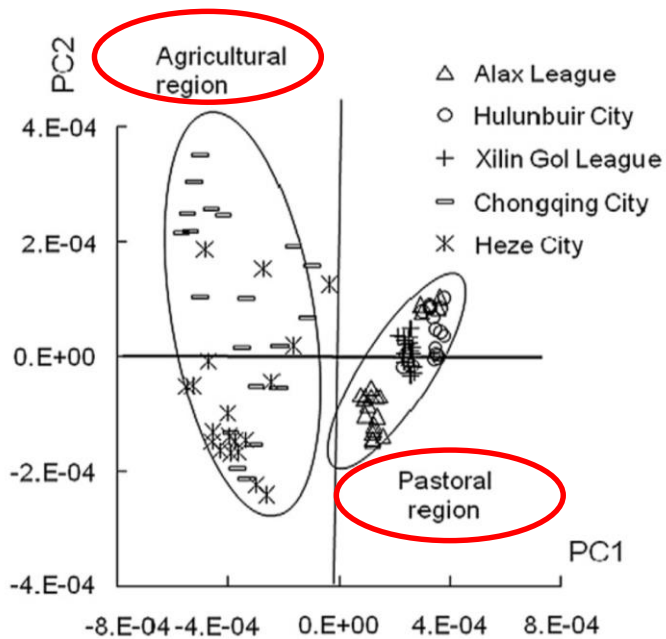
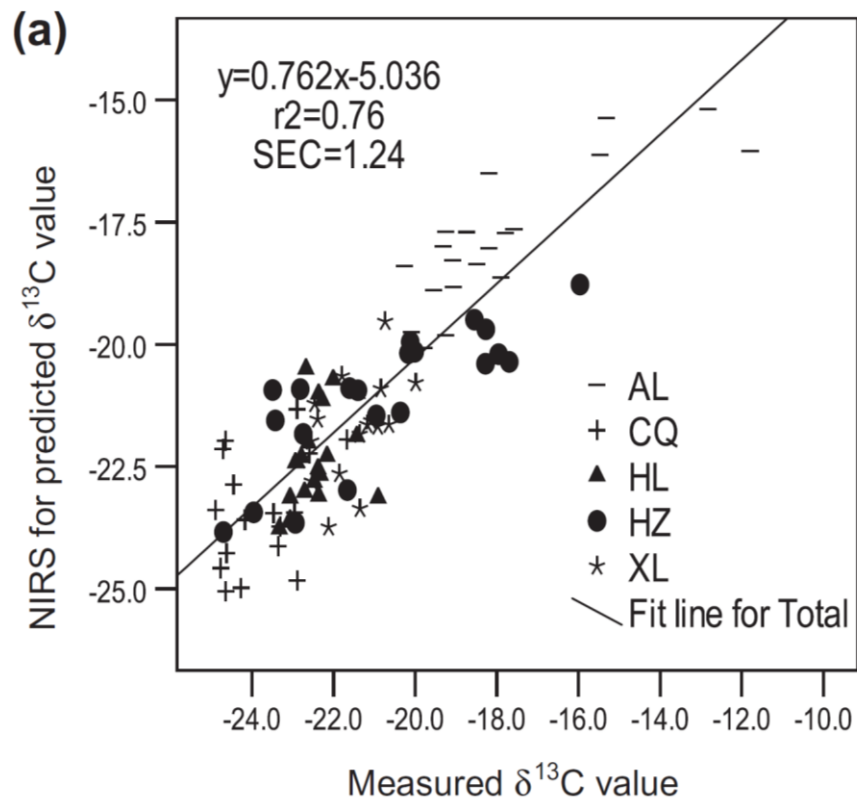


Fig. 1. Score plot of first two PCs of defatted lamb meat samples from different regions based on NIR second derivative (Savitzky-Golay, 5 point) and MSC transformation spectra.



Sun et al. 2012, Food Chemistry, 135,508.

Conclusions

- **Range of markers** available with potential to authenticate dietary background and geographical origin
- **Limitations/challenges**
 - cost and speed of analysis
 - samples from controlled studies
 - seasonal variation
 - diet switches (what feed constituents, when, and for how long?)
 - trade in animal feedstuffs

Conclusions

- **Solutions**

Rapid methods

Data-bases underpinning labels, e.g. grass-fed, country of origin, organic

Understanding:

- turnover of tissues in response to a diet change
- seasonal variation in marker compounds

Measurement of **multiple markers** make it less likely to “fake it”

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Prof Aidan Moloney	Teagasc
Prof Olaf Schmidt	UCD
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Dr Teresa Osorio-Arguelo	Post doc
Florian Roehrle	PhD student
Dr Antoine Zazzo	Post doc

