Re-Livestock

RESILIENT FARMING SYSTEMS

Examples of implementation of methane traits in breeding programs: Spain

Oscar González-Recio

INIA CSIC

Zaragoza, February 27th, 2025

Overview of breeding programs

Steps in a breeding program

1. **Define breeding objectives**
   - Profit function, bioeconomical model, desired responses, etc
   - Relative weight of traits to be selected in the overall breeding goal or selection index
2. **Recording scheme**
3. **Create a reference population**
   - Animals with genotype and phenotype (own records or progeny tests)
4. **Genetic evaluations** (genomic using molecular information)
   - Reference population
   - Genotyped animals in the candidate population (probably using imputation techniques if genotyping density differs from that of the reference population)
5. **Selection of breeders for the next generation (dissemination)**
   - sires of bulls
   - dams of bulls
   - sires of cows
   - dams of cows

Overview of breeding programs

Establishing a reference population for methane - Costs of phenotyping

J. Dairy Sci. 97:7905–7915
http://dx.doi.org/10.3168/jds.2014-8125

On the value of the phenotypes in the genomic era

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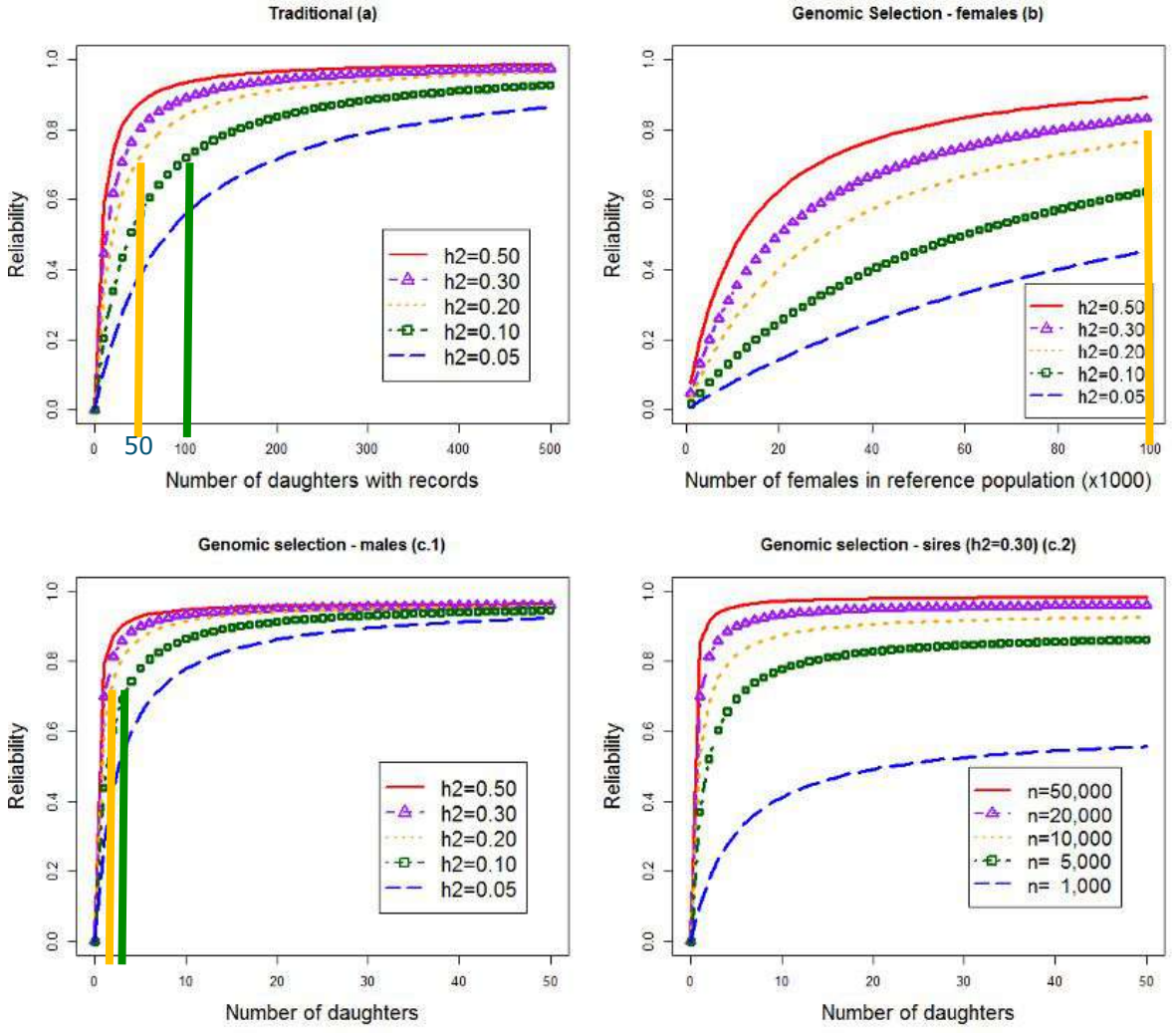
Achieve 70% theoretical EBV reliability

Traditional breeding: progeny groups between 50-100 daughters

Genomic selection (sire reference population): progeny ~5 daughters

Genomic selection (cow reference population): 100k to 500k cows



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Overview of breeding programs

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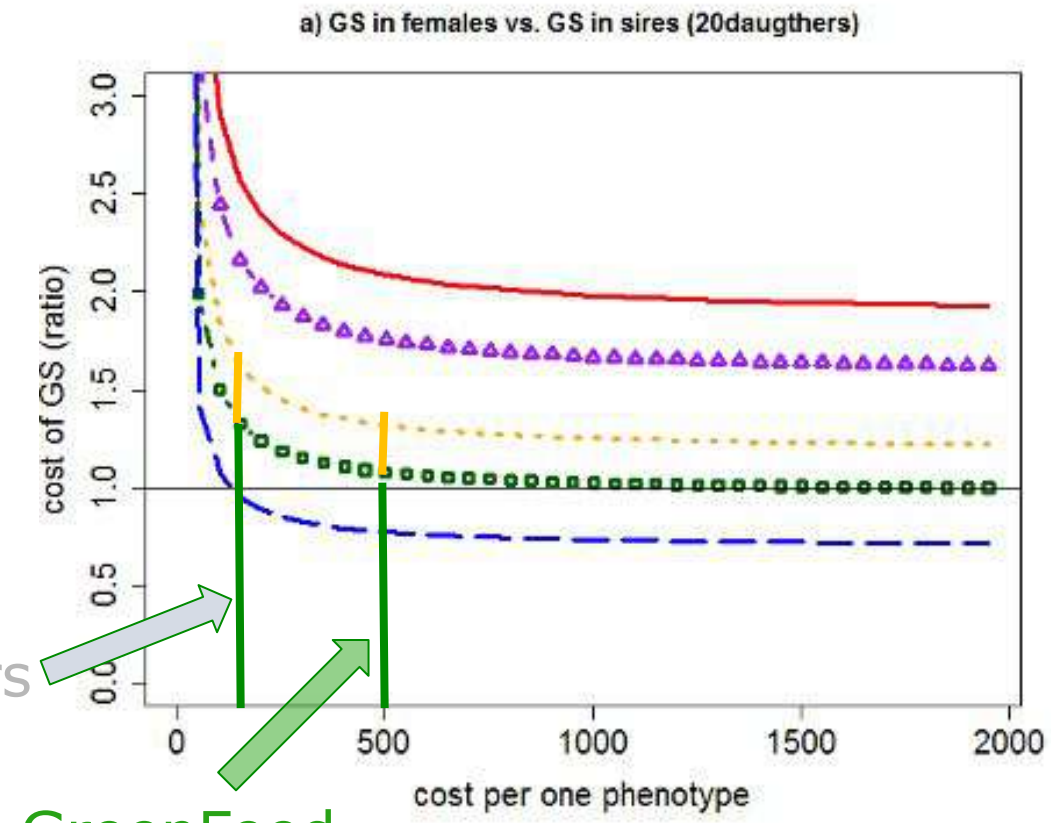
Phenotyping-Genotyping strategy



Sniffers

GreenFeed

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Situation in Spanish dairy breeding program

- **Reference population**
  - Holstein cows (~1000 cows per year, progeny groups for 200 sires)
  - Sires and cows genotyped

- **Genetic evaluations for methane traits (progress this far)**

- **Including methane in the breeding goal of Spanish Dairy Cattle (future perspectives)**

METHANE PHENOTYPING

3500 cows
37 farms

metalgen
NEIKER
MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

INIA
Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria

CONFEDERACIÓN DE ASOCIACIONES DE FRISONA ESPAÑOLA
CONAFE

Precision farming

Genotypes (50k SNPs)

Genotypes (50k SNPs)

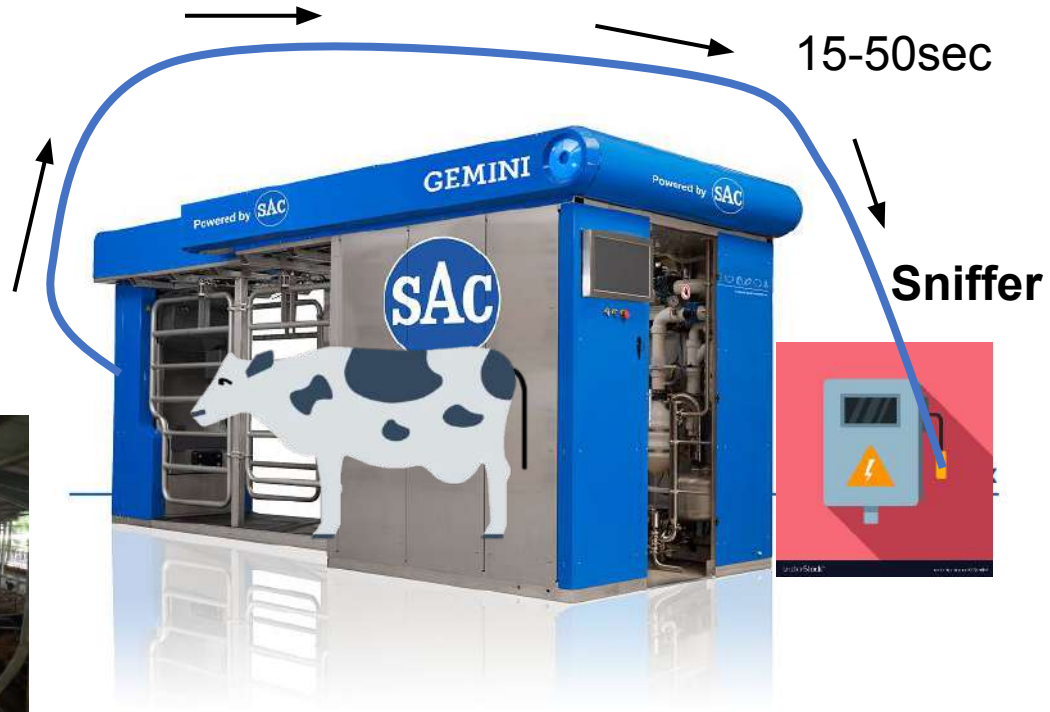
METHANE PHENOTYPING

1. Recording methane in commercial and experimental farms

Samples= 3500 dairy cows in 37 farms

Genetic evaluations

- **Based on direct measurements**
  - from sniffers in commercial farms
  - Extracted from of eructation events



- **SingleStep Genomic BLUP**
  - $CH_4 = \mu + FatYield + Npar + Herd\text{-}Robot\text{-}Period + DIM + MonthParity + PERM + ADIT + e$
  - $h^2 = 0.17$
  - $r^2 = 0.66$
- **~3.500 animals as reference population (15.000 observations)**
- **360,000 animals in pedigree (118,000 genotyped)**

Genetic evaluations

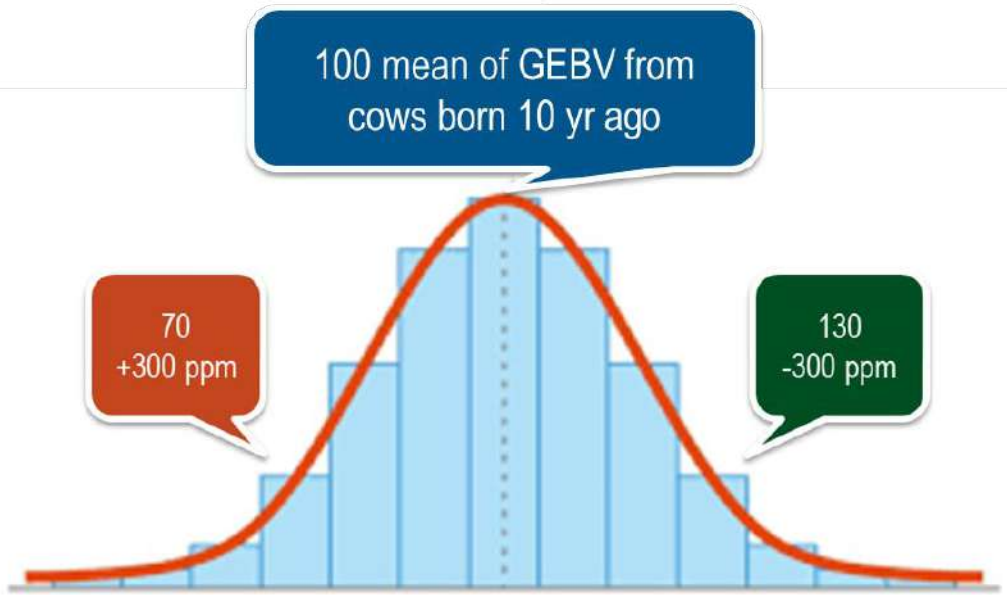
Published as an individual trait in the catalog.

200 Mejores Toros del Catálogo

Nº	Número	Nombre	Año nac.	Kg. Leche	% Grasa	Kg. Grasa	% Prot.	Kg. Prot.	Fiab. Prod.	IPP	ICU	IGT	RCS	Long.	Fiab Long.	DA	Fiab. DA	FPD	Fiab. FPD	ISP	VOR	MET	IMET Leche	ICO	Perc.
1	CANM0012773216	SILVERRIDGE V TIMBERLAKE ET	2017	2034	-0,06	66	0,03	69	98	-0,81	1,62	0,98	112	122	65	102	76	115	82		103	110	328	1266	99
2	ESPM9204523525	NEMO G SANTI ET	2017	1444	0,18	72	0,08	55	95	1,86	1,12	1,57	126	113	59	95	68	118	73	111	97	100	287	1265	99
3	ESPM9204695956	K&L OH ROSSI GUAY	2018	752	0,42	70	0,18	43	98	0,88	2,19	1,9	119	123	59	109	68	112	94		79	66	274	1262	99
4	ESPM9204501760	LIEU THOMAIN BALTAZAR ET	2017	1132	0,26	68	0,12	49	84	1,3	1,14	1,08	119	121	55	107	65	109	55	113	92	115	286	1258	99
5	ESPM9204691049	SALUD ET	2017	1118	0,18	59	-0,02	34	93	2,88	1,35	1,64	125	120	57	100	66	114	82		89	96	263	1257	99
6	ESPM9204634816	SALVUS ET	2017	1520	-0,24	28	-0,08	40	97	1,01	1,87	1,36	132	124	57	108	66	108	88		74	100	251	1255	99
7	ESPM9204741024	PALMER ET	2018	925	-0,04	29	0,13	44	91	1,59	2,34	2,15	115	126	55	112	65	108	93		100	99	260	1253	99
8	ESPM9204828913	TIRSVAD HOTSPOT HONDO ET	2019	672	0,05	29	0,14	36	80	2	1,73	1,69	118	130	53	123	63	119	90		99	107	263	1253	99
9	ESPM9204628506	MANDY KODAK ET	2017	1736	0,12	76	0,01	57	93	0,42	0,98	1,22	118	116	55	99	65	101	55	110	109	83	282	1252	99
10	ESPM9204595970	HUNTER K&L SV ADRIAN SALVATIER	2017	993	0,13	49	0,12	45	93	1,13	1,4	0,9	125	123	57	107	66	116	82	116	88	90	275	1252	99
11	840M3130915944	COOKIECUTTER LGND HUSKY ET	2017	1488	-0,08	45	-0,07	40	98	-0,95	1,92	0,93	117	135	67	114	74	102	78		96	99	278	1251	99
12	ESPM2704487908	GRILO SANRECAM LUCKY ET	2017	1524	0,16	72	0,09	59	85	0,93	1,22	1,21	107	112	59	103	68	109	67	109	98	108	284	1250	99
13	840M3128557570	ABS MEDLEY ET	2015	1296	0,25	74	0,13	56	98	0,46	0,67	0,51	108	125	74	106	78	120	78		108	106	302	1249	99
14	ESPM9204631171	VEKIS RISK	2017	1104	0,05	45	0,05	41	90	0,92	1,02	1	120	131	61	116	68	115	65	113	83	98	267	1249	99
15	840M3138310311	REDROCK-VIEW KLUTCH ET	2016	783	0,13	41	0,16	42	99	-0,91	2,28	1,33	124	131	74	120	78	114	80		86	95	260	1249	99
16	ESPM9204630024	BANANA JOE ET	2017	1138	0,18	60	0,11	49	93	1,29	1,18	1,15	119	119	53	112	61	106	68	110	96	103	270	1247	99
17	ESPM9204631169	CLEVELAND SALARIO ET	2017	1113	0,11	52	0,08	45	98	1,4	1,53	1,54	124	116	57	109	65	120	88		100	96	264	1245	99
18	ESPM9204739617	MUGABE ET	2018	1455	-0,15	36	0,02	49	80	0,46	1,37	1,05	116	128	52	113	61	109	52		100	106	273	1245	99
19	ESPM9204595969	GYMNAST GENIAL ET	2017	1657	0,08	68	0,05	59	99	0,67	1,79	1,5	125	109	57	88	66	114	94	111	64	78	260	1244	99
20	ESPM9204631170	K&L POPPE GOAL	2017	995	0,14	50	0,05	38	99	1,52	2,07	1,83	118	121	55	105	65	95	93		115	103	255	1243	99
21	ESPM9204631173	SALVAT RED ET	2017	1579	-0,27	26	-0,04	46	85	1,18	1,16	0,86	131	118	55	107	65	115	55	115	88	91	252	1242	99
22	840M3132352752	ST GEN R-HAZE RAPID ET	2017	1055	0,37	77	0,16	51	95	1,46	1,4	1,69	96	120	69	104	76	109	79		117	104	289	1240	99

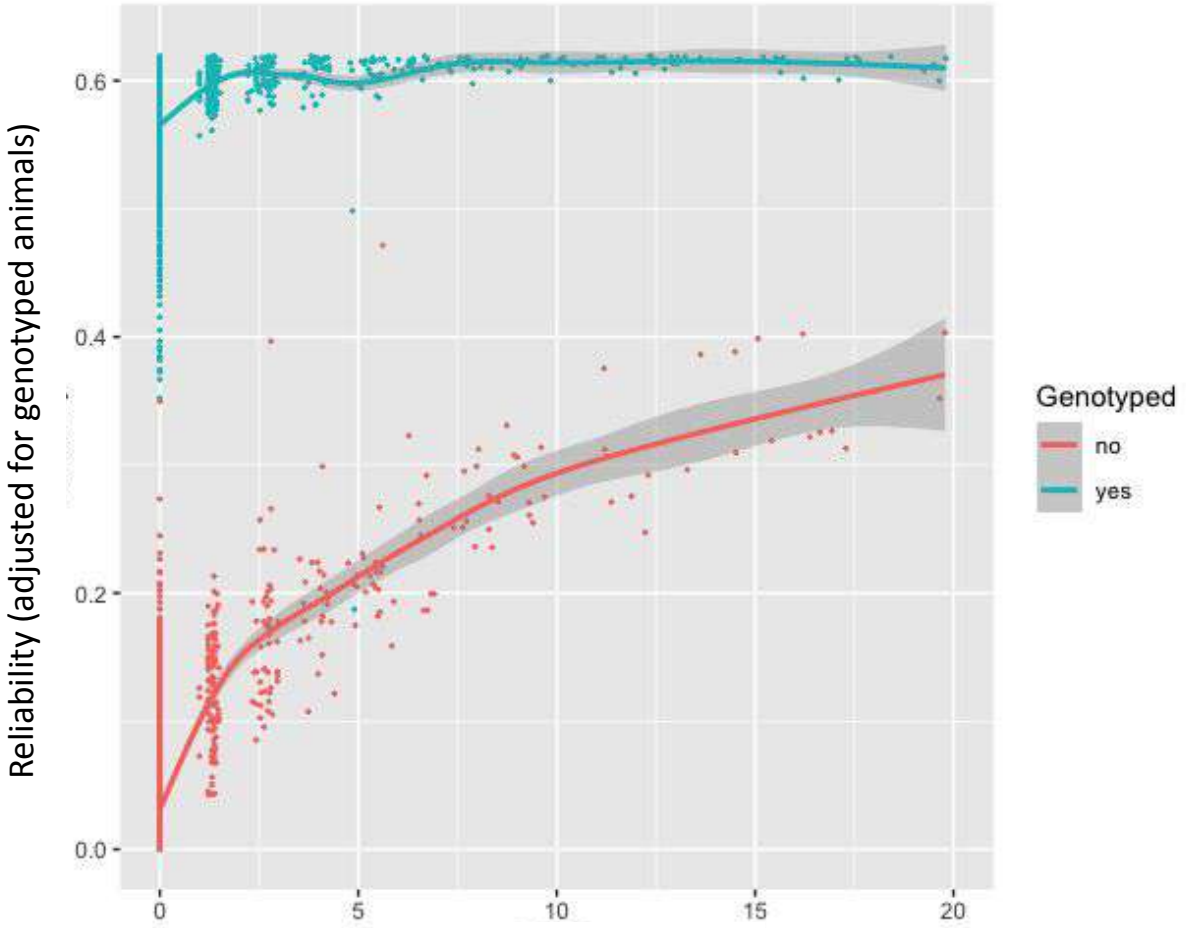
Genetic evaluations

- **GEBV published as mean=100 and sd=10**

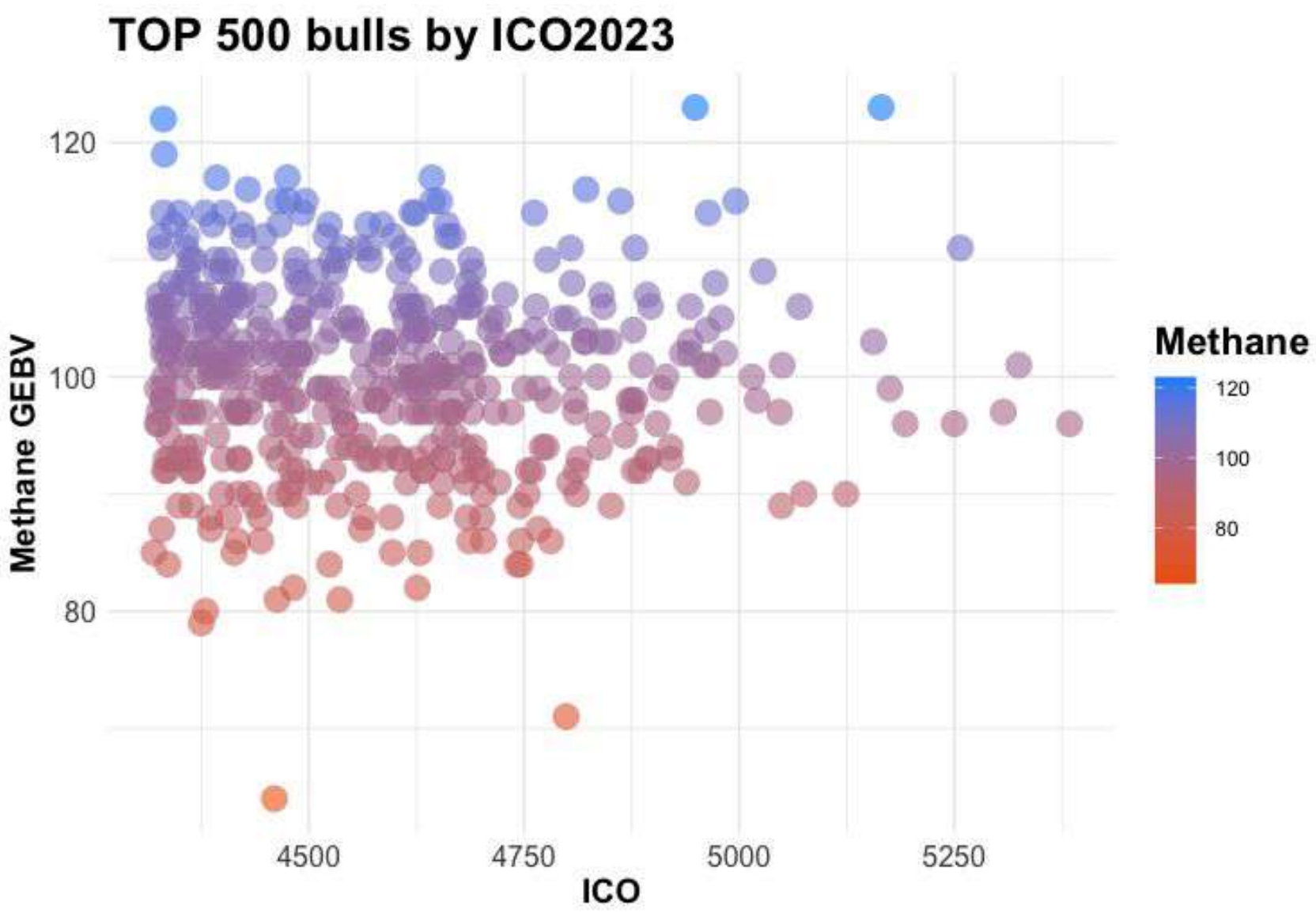


Bulls with daughters emitting more methane

Bulls with daughters emitting more methane

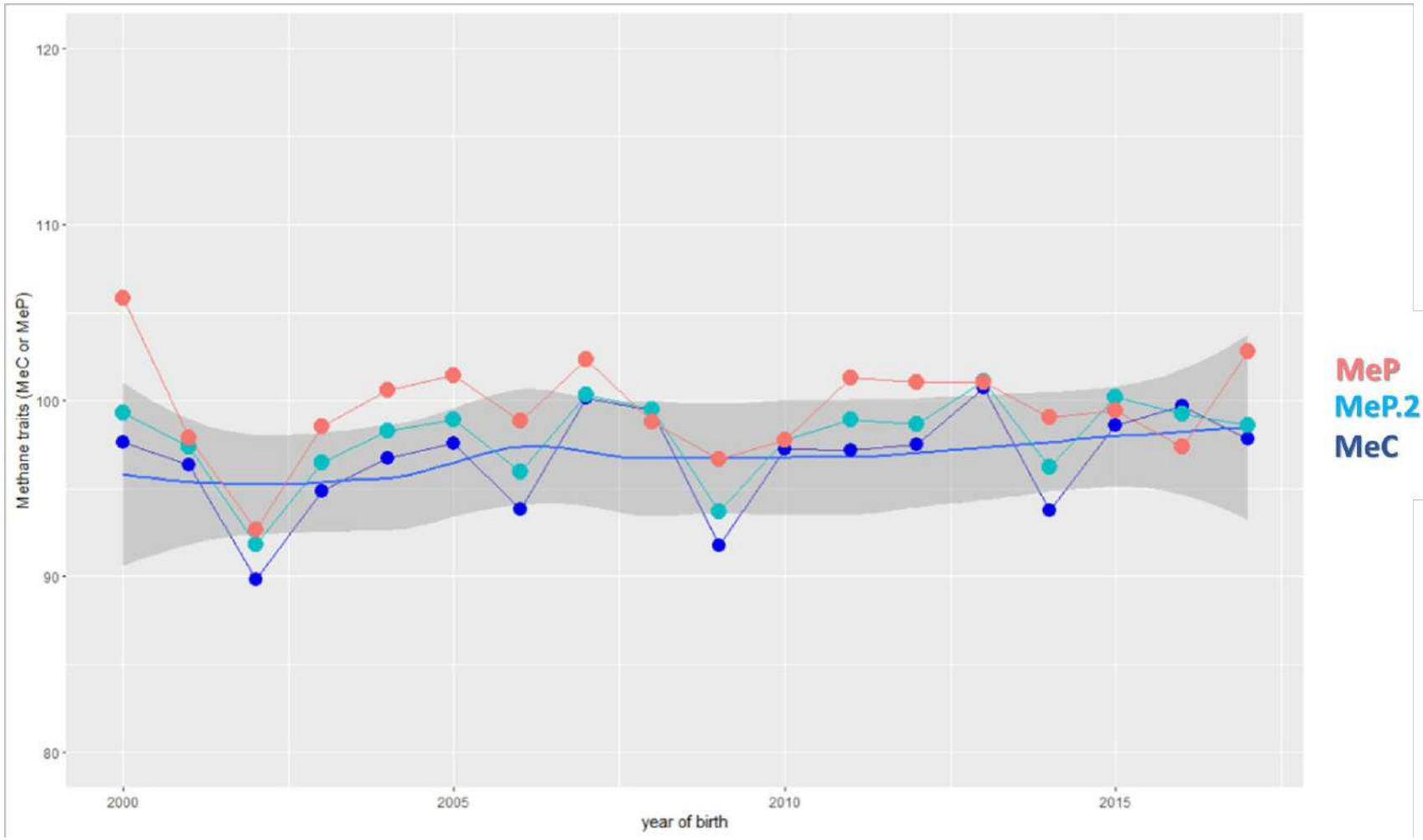


Genetic evaluations

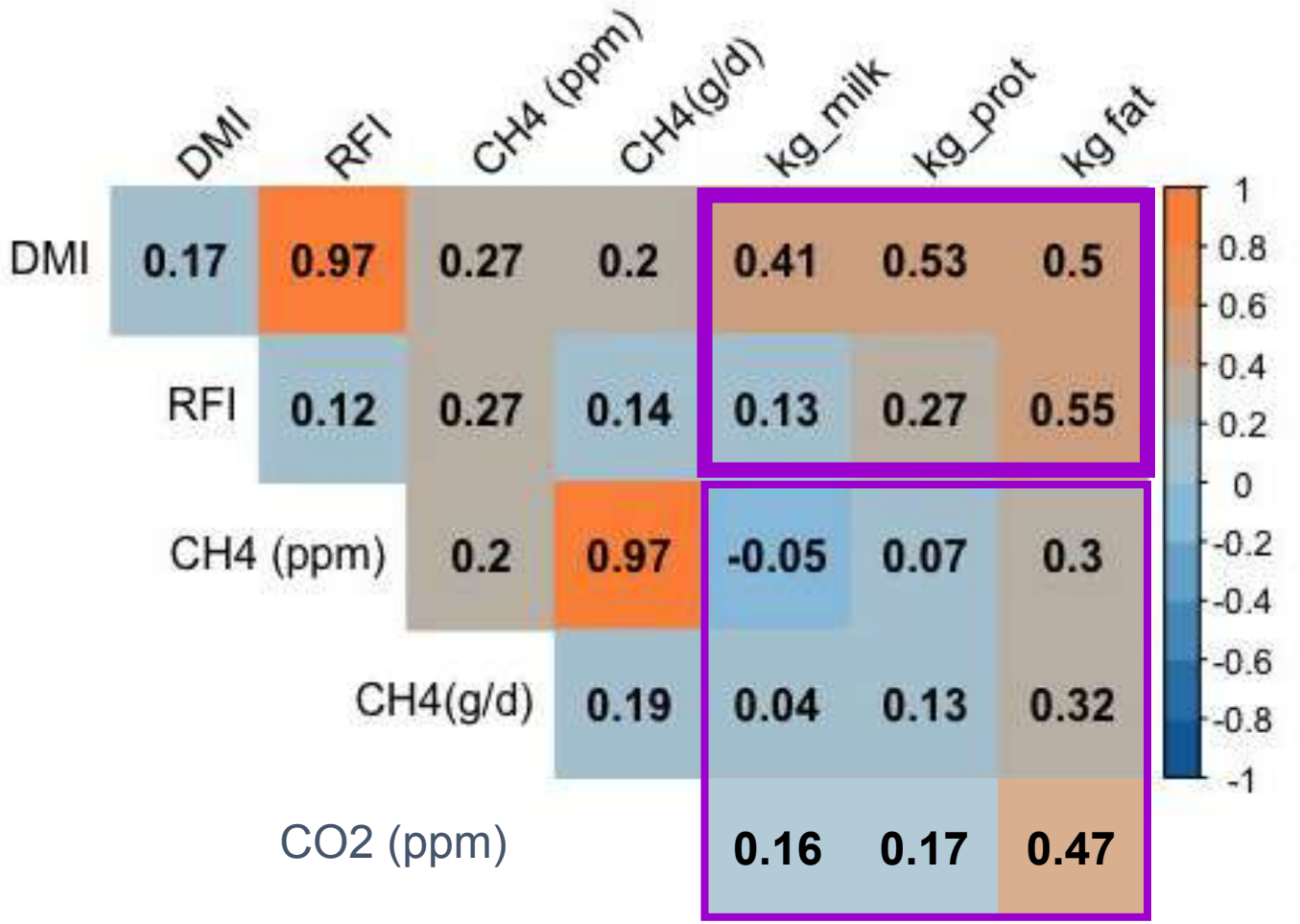


Methane genetic trend

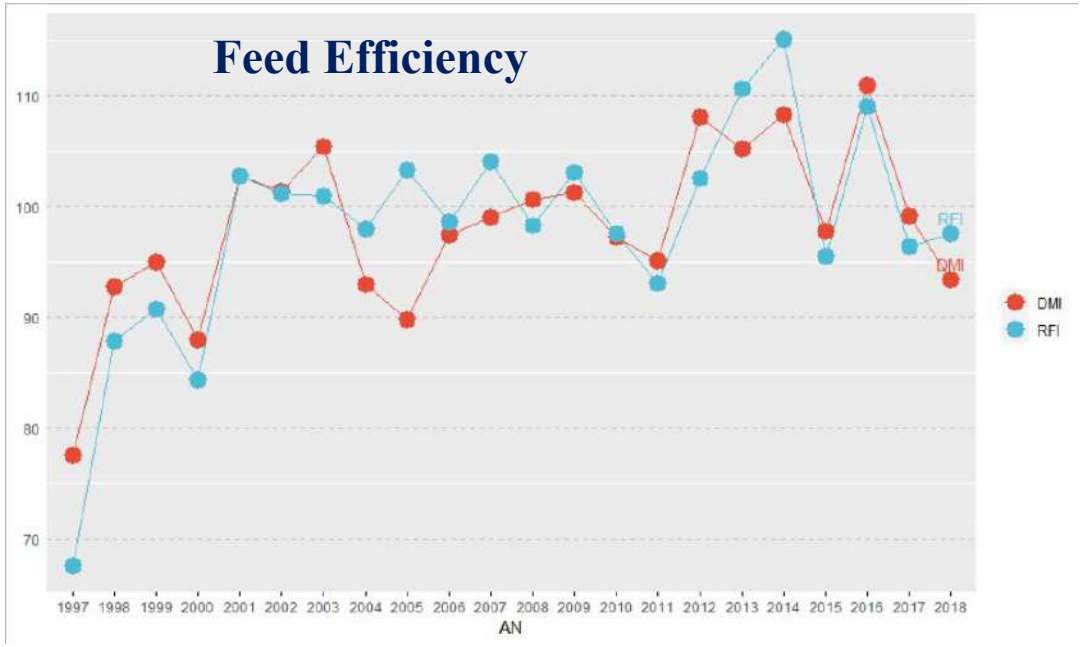
- **No genetic trend was observed**

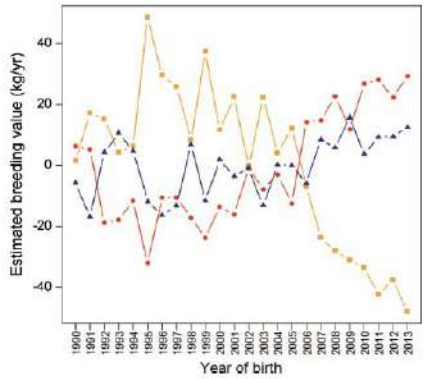


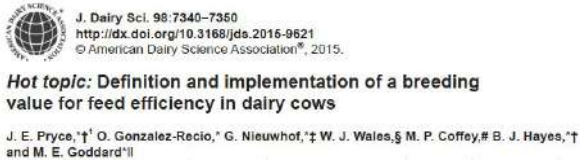
Genetic correlations



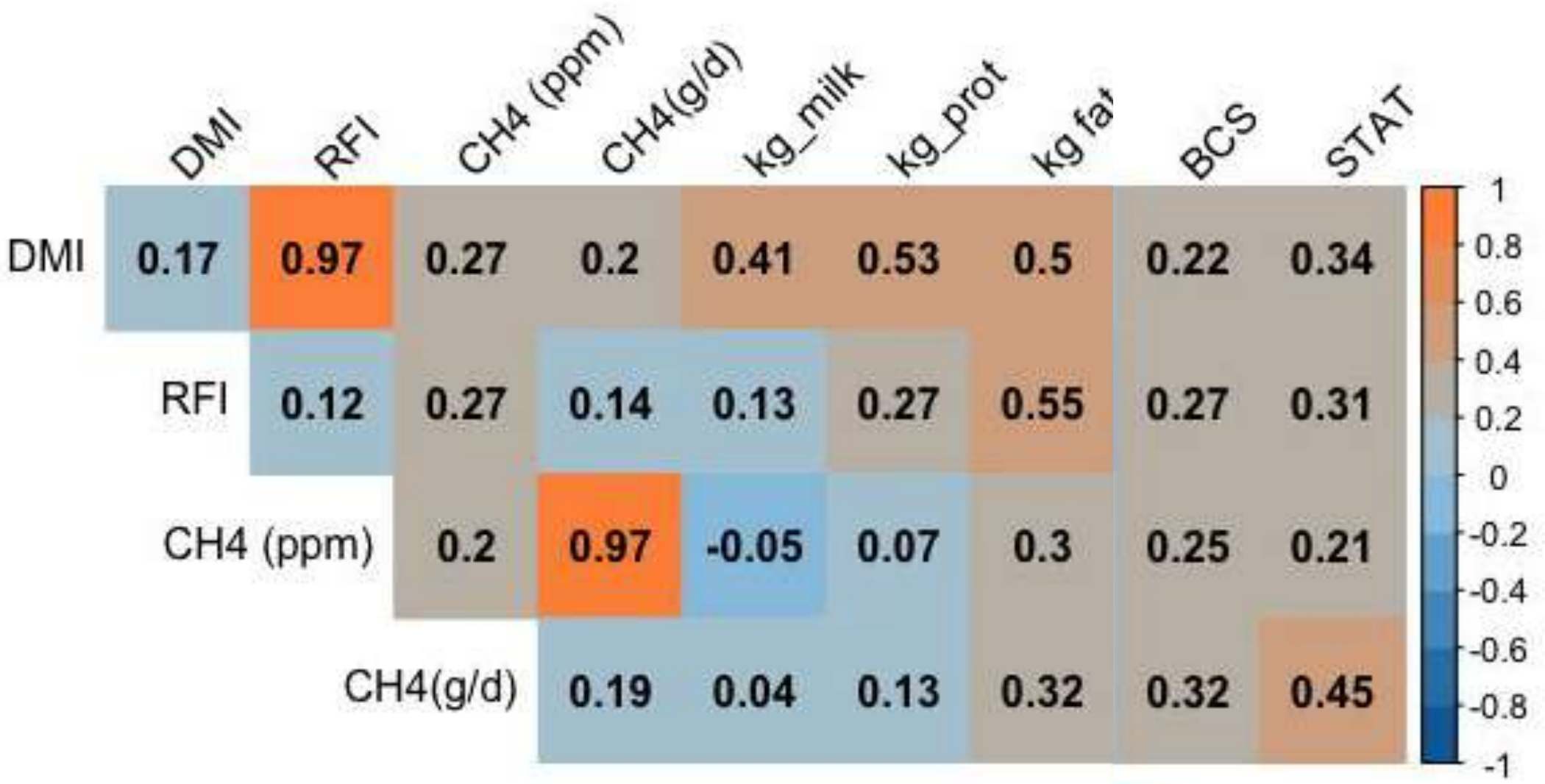
Genetic trendsx







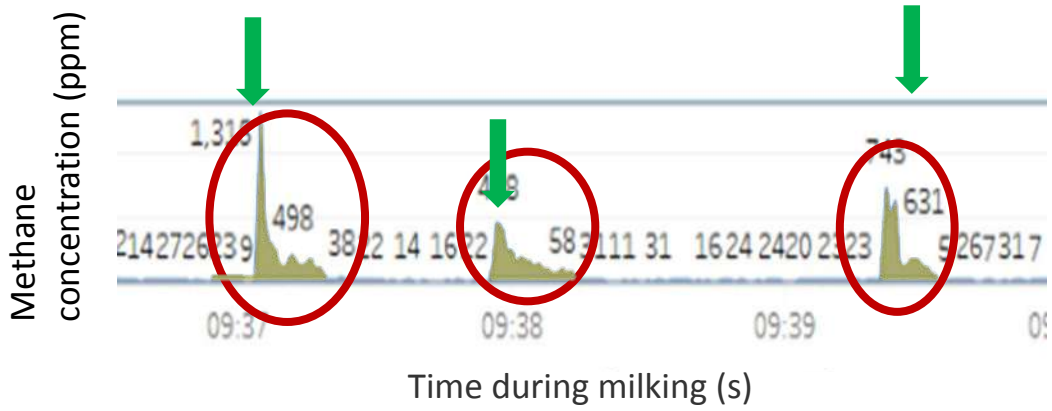
Genetic correlations with other traits



METHANE PHENOTYPING

- **Phenotype definition (weekly averages)**

1. Mean CH_4 (by second and every 5 s)
2. Sum of peaks CH_4 (by second and every 5 s)
3. Sum of max peaks CH_4
4. Area under the curve (AUC CH_4)
5. Ratio of (mean) CH_4/CO_2
6. CH_4 grams per day (Madsen et al., 2010)



$$\text{Prod } CH_4\left(\frac{g}{d}\right) = 0.714 * \boldsymbol{ratio(ppm)} * 180 * 24 * 0.001 * (5.6 * kg\ body\ mass^{0.75}) + 22 * \boldsymbol{ECM} + 1.6{*}10^{-5} * days\ in\ pregnancy$$

7. CH_4 grams per day (in-house*, based on observed CO2 and CH4/CO2 ratio, *to be published*)

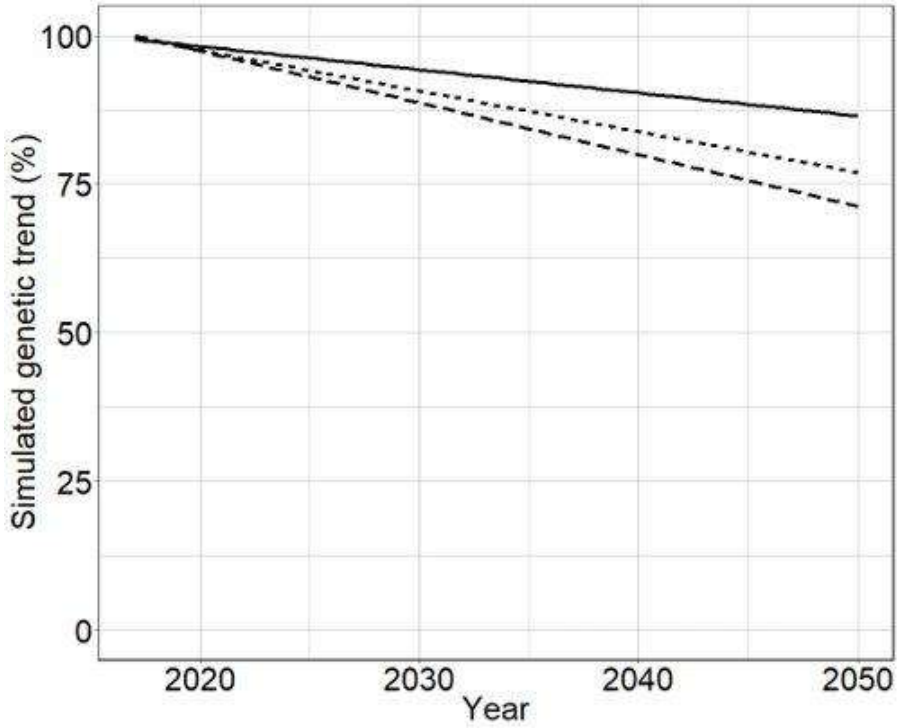
Large genetic correlation between phenotypes

Methane emissions in breeding goals and selection indices

Animal breeding as a mitigation strategy

Methane intensity (g/kg milk) & methane emissions (g/d)

- Current trend
- Combined selection for CH4 and other traits
- Theoretical maximum (exclusively focusing on methane)



https://doi.org/10.1016/j.animal.2021.100294
(de Haas *et al.* 2021)

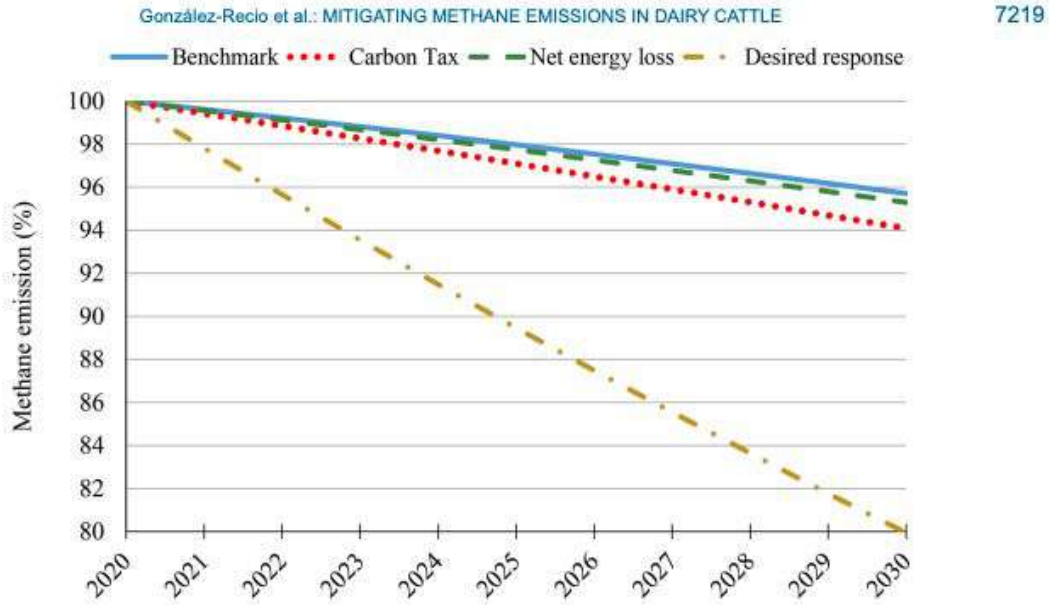
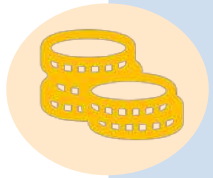


Figure 2. Expected reduction in percentage from current levels in methane emissions produced by Holstein cows in Spain based on genetic gain in methane emissions (MET; t/yr) under the 4 scenarios: benchmark, carbon tax, net energy loss, and desired response (i.e., number of cows × MET genetic gain × time/1,000). A decrease of 1.5% in the number of dairy cows was considered each year, following census data from the Spanish Holstein association: (http://www.conafe.com/VisorDocs.aspx?pdf=estadisticas_CENSO_DE_ANIMALES.pdf).

Economic Selection indices proposed in Spain (IM€T)

Traditional, Pasture-based, Cheese, Organic



Breeding goals

- Production
- Mastitis & Lameness
- Feed Efficiency
- Fertility
- Longevity
- Live Weight
- Calving Ease
- Methane production (g/d)

Economic value Feed intake:

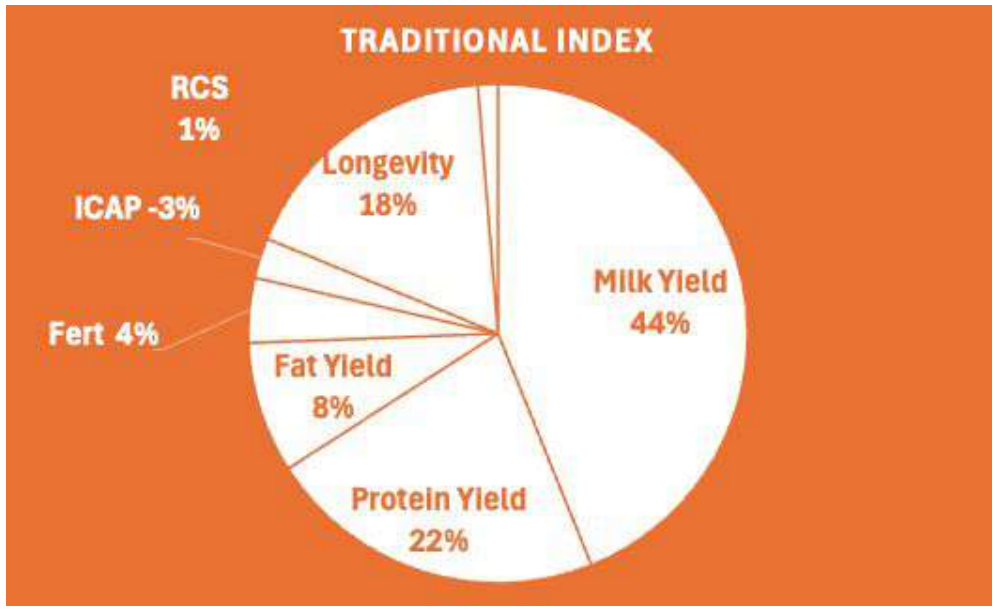
- Cost of MFU per kg DM

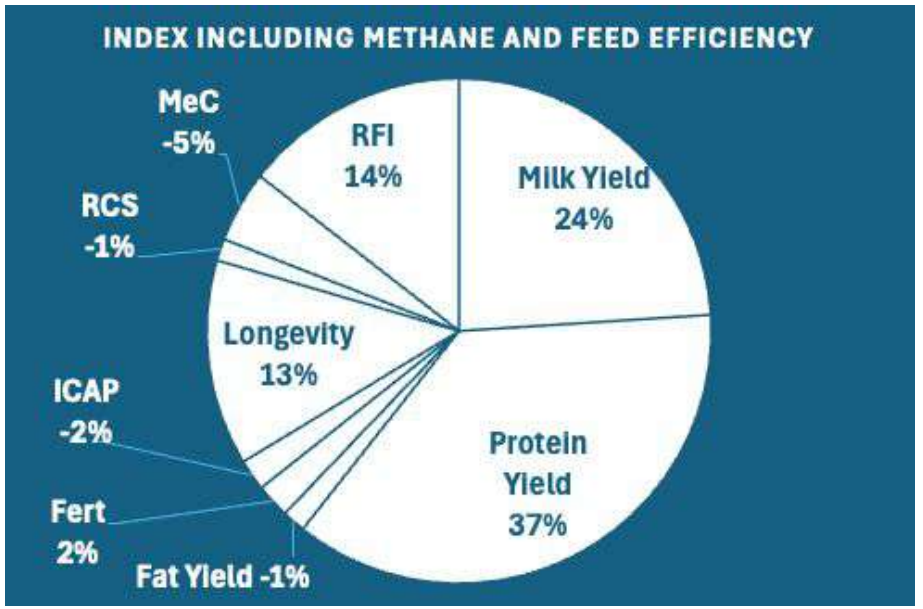
Economic value methane:

- Carbon price voluntary market for traditional systems -0.14 € (g/d/cow)
- Carbon price for organic systems -0.72 € (g/d/cow)

Example of implementation

- **Efficiency and sustainability index in Spanish Dairy cattle**
  - Subindex (will be integrated in the total merit index)



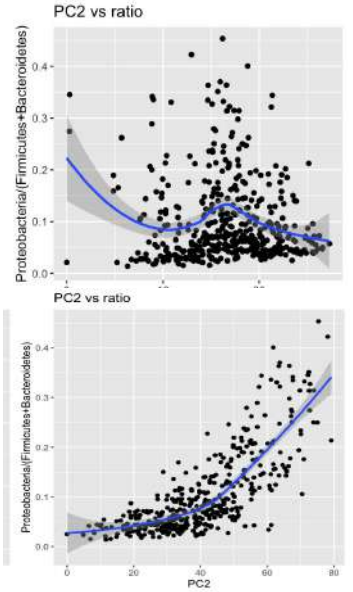


- Calculate expected genetic gain for each trait, including the correlated response on the microbial aggregated variables.

Genetic correlations: Rumen microbiome community

Genetic correlation between PC and other traits

	PC1T	PC2T	PC1F	PC2F	MY	PY	FY	MeC	MeP	DMI	RFI
PC1T	1	-0.02	0.97	0.61	0.2	0.21	-0.35	-0.7	-0.67	-0.44	-0.54
PC2T		1	0.16	0.4	-0.03	-0.18	-0.3	-0.13	-0.34	-0.46	-0.38
PC1F			1	0.19	0.23	0.4	-0.23	-0.57	-0.53	-0.23	-0.36
PC2F				1	0.08	0.08	-0.33	-0.23	-0.36	-0.18	-0.29



- Aggregated microbial variables have heritabilites 0.20-0.30.
- Aggregated microbial variables are favorably genetically correlated with milk, protein, methane emissions and feed efficiency (unfavorable with fat).
- Inclusion of aggregated variables in the SI improved genetic response for production traits.
- Breeding for lower methane or feed efficiency may impact microbiota composition (dysbiosis)
- What are the expected consequences?

TAKE HOME MESSAGE

01

Need large reference populations

02

In-depth discussion on methane reduction targets, and incentives to farmers and breeding programs

03

Rumen microbiome information is a suitable complementary phenotype for reducing methane emissions

Selecting for lower emissions and better feed efficiency may impact rumen microbiome health, and it should be controlled