



Phenotyping strategies to enhance genetic gain for animal health and welfare in dairy cattle – from the past to future perspectives

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Session 57

C. Egger-Danner, A. Köck, C. Fuerst, H. Schwarzenbacher, **K. Schodl**, J. Himmelbauer, B. Fuerst-Waltl

Contact: egger-danner@zuchtdata.at

Requirements for a 'sustainable' cow

Efficient and healthy, economical, low ecological footprint

Breeding goals:

- high milk yield
- high feed efficiency
- good fertility
- long productive life
- good milk quality - healthy udders
- no or few claw problems
- no or few problems with metabolism
- resilient (heat stress,...)
- low emissions
- good carcass and meat quality

Further requirements:

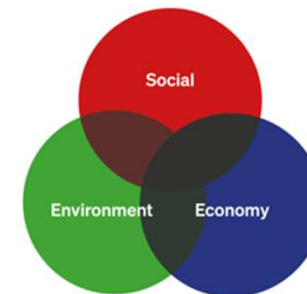
- animal welfare
- low ecological footprint / fewer emissions - climate targets 2030/2040
- low use of antimicrobials



Picture: HBLFA Raumberg-Gumpenstein



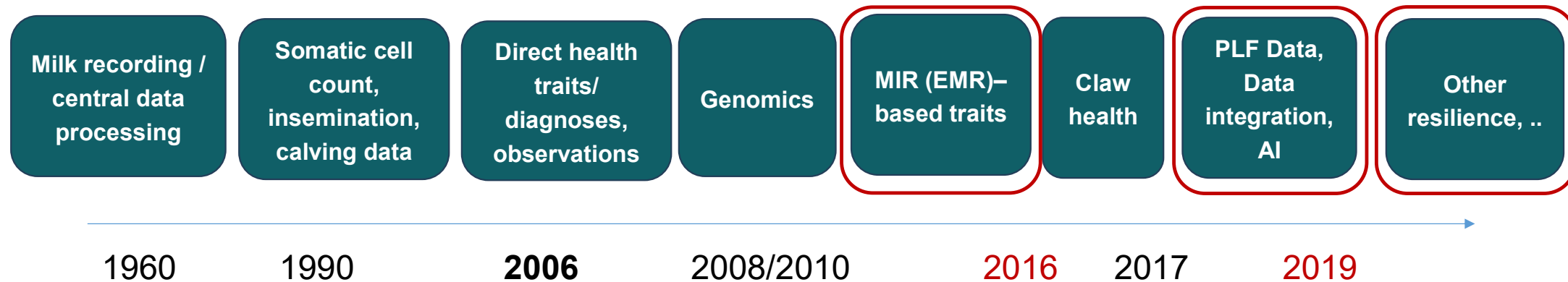
many challenges



**ENSURE BETTER
BREEDING TO
ENHANCE RESILIENCE
AND SUSTAINABILITY**

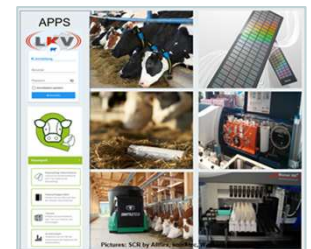
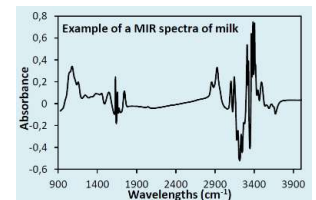
More and more traits / balanced breeding goal / different dimensions! Phenotyping key!

Phenotyping schemes in Austria – from the past to the future



(New) Data / Auxiliary Traits for Breeding and Management

- **Mid-infrared (MIR) spectroscopy** estimators from milk samples are available at each milk recording.
- **New data/traits are derived using algorithms** from automatic milking systems, sensor systems, ... The use of such technologies is increasing rapidly.



Phenotyping – general considerations



- **Traits** (heritability/repeatability)
 - **Direct/target traits** of interest to improve, e.g. health disorders
 - **Indirect traits** with genetic correlation to the target trait
- **Combination of phenotype and genotype** – recording only in 'test' herds?
- **Number of phenotypes** and **reliability** of breeding values
- Ease of recording/availability/**cost of recording**

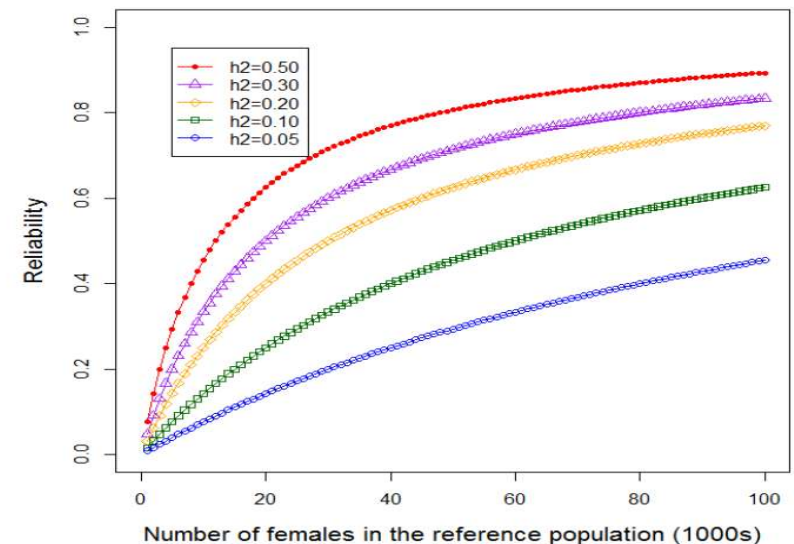
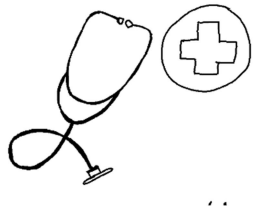


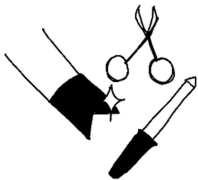
Figure 1. Expected reliability for reference populations of 0 to 100,000 (from (Gonzalez-Recio, 2014))

What is the optimal combination of direct and indirect traits considering reliability of breeding values, genetic gain and costs?

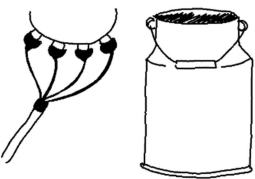
Recording of „direct“ traits



Veterinary diagnoses



Claw trimming data



Lab data

Advantages:

- Detailed information, targeted genetic improvement possible
e.g. reduce dermatitis digitalis (DD) incidence by breeding
- ‘Gold standard’ for developing new features/algorithms
- Validation/check of development with auxiliary features
→ do we move into the right direction?

Disadvantages:

- Standardisation needed
- Cooperation of veterinarians, claw trimmers → all on board?
- Cost of phenotyping

Direct traits are always needed – but to which extent?

New data / traits for breeding



High potential for auxiliary traits related to fertility and health

• Fertility

- **Traditional:** based on insemination, calving, and diagnoses (h^2 : 0.01–0.02)
- Oestrus intensity and duration
- Interval to first high activity
- Progesterone, luteal activity

New traits:
Heritabilities 0.05 – 0.18

• Metabolic stability

- **Direct:** diagnoses (h^2 : 0.01–0.05/0.10), ketosis tests (h^2 : 0.05–0.22)
- Fat-to-protein ratio, observations, culling
- **MIR-based predictors (high potential)**
- **Sensor measurements (e.g. rumination)**
- Deviations from the lactation curve
- Body Condition Score (BCS)



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Invited review: Using data from sensors and other precision farming technologies to enhance the sustainability of dairy cattle breeding programs

Luiz F. Brito,^{1*} Bjørge Heringstad,² Ilka Christine Klaas,³ Katharina Schodl,⁴ Victor E. Cabrera,⁵ Anna Stygar,⁶ Michael Iwersen,⁷ Marie J. Haskell,⁸ Kathrin F. Stock,⁹ Nicolas Gengler,¹⁰ Jeffrey Bewley,¹¹ Miel Hostens,¹² Elsa Vasseur,¹³ and Christa Egger-Danner⁴

MIR derived traits for BHB



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- **Heritability of MIR-BHB ranged from 0.13 to 0.18**, varying only marginally across lactation periods
- Negative genetic correlation with protein%;
Positive with milk yield, fat:protein ratio, and fat%
- Genetic correlations showed stronger shifts across days in milk
- **Strong genetic correlation with blood BHB** (0.65 ± 0.16) and **clinical ketosis** (0.84 ± 0.46)
- **Supports MIR spectra as a heritable proxy for ketosis** in dairy cattle genetic evaluation
- **Availability:** Available for all cows within milk recording
- Implementation into routine genetic evaluation in progress.

Other studies support results:

KetoMIR: h^2 0.15 – 0.30
Ketosis r_g 0.60 – 0.73

(Fürst-Waltl et al. 2022;
Köck et al. 2024)



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Prediction and genetic analysis of blood β -hydroxybutyrate based on milk mid-infrared spectra in Fleckvieh dairy cows

Stefan Gruber,^{1*} Astrid Köck,² Christa Egger-Danner,² Michael Iwersen,³
Birgit Fuerst-Waltl,¹ and Johann Sölkner¹

¹Department of Agricultural Sciences, Institute of Livestock Sciences, BOKU University, 1180 Vienna, Austria

²ZuchtData EDV-Dienstleistungen GmbH, 1200 Vienna, Austria

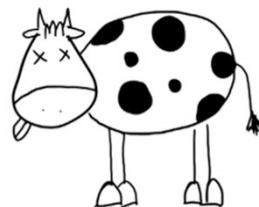
³Clinic for Ruminants, Ludwig-Maximilians-Universität Munich, 85764 Oberschleißheim, Germany

Genetic parameters sensor data (Schodl et al. 2026)



Lactation days 1-30	h^2 (S.E.)	Genet. Korr. Ketose
 Activity (30-day mean)	0.23 (0.05)	-0.93 (0.19)
 Activity (30-day mean)	0.18 (0.03)	-0.67 (0.30)
 Activity (30-day SD)	0.34 (0.04)	-0.67 (0.17)

Source: Schodl et al. - submitted to Journal of Dairy Science



The traits derived from sensor data are heritable and show a high correlation with ketosis in early lactation. The challenge is using the data for routine breeding value estimation.

New data / traits for breeding



- **Udder health**

- **Direct traits:** diagnoses, bacteriological milk testing (h^2 : 0.01–0.05)
- **Cullings** due to udder problems, linear conformation traits, lactose content
- MIR-based mastitis predictors (D4Dairy: limited additional benefit)
- AMS data: electrical conductivity, deviations lactation curve,...
- Sensor-derived traits: activity, rumination, alerts,...

**New AMS and
sensor data**
More research / data

- **Claw health / lameness**

- **Direct traits:** claw-trimming records (h^2 : 0.01–0.15), veterinary diagnoses for claw lesion (h^2 : 0.01–0.05)
- **Lameness, claw position score:** $h^2 \approx 0.05$ –0.10; high genetic correlations with claw disorders → promising indicator traits
- Cullings, linear conformation traits
- Pressure plates, video-based methods
- **Sensor data: activity**, lying behaviour, feeding, milking visits

**Technologies still under
development** – so far,
mainly severe cases can
be detected.

Lameness and behaviour (Lemmens et al. 2023)

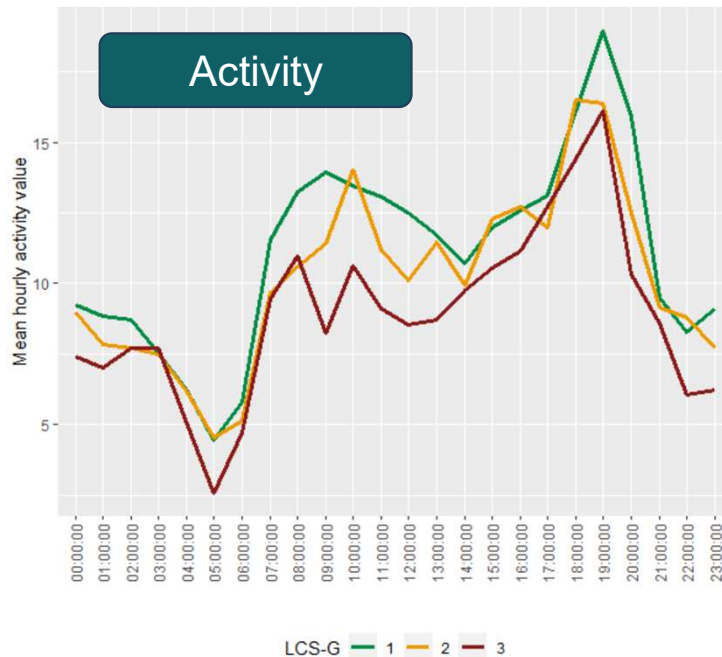


Figure S2: Mean hourly activity values (in minutes) for sensor parameter 'Eating' showing a visible reduction for LCS-G 2 and LCS-G 3 cows.

> *Animals (Basel)*. 2023 Mar 28;13(7):1180. doi: 10.3390/ani13071180.

The Combined Use of Automated Milking System and Sensor Data to Improve Detection of Mild Lameness in Dairy Cattle

Lena Lemmens ¹, Katharina Schodl ², Birgit Fuerst-Waltl ², Hermann Schwarzenbacher ³, Christa Egger-Danner ³, Kristina Linke ³, Marlene Suntinger ³, Mary Phelan ⁴, Martin Mayerhofer ³, Franz Steininger ³, Franz Papst ^{5,6}, Lorenz Maurer ², Johann Kofler ¹



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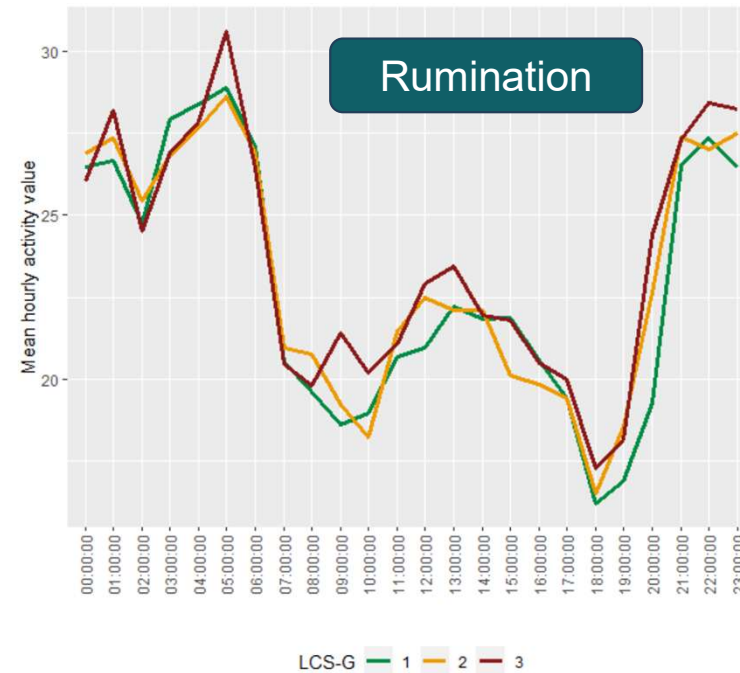


Figure S1: Mean hourly activity values (in minutes) for sensor parameter 'Rumination' showing no visible reduction for LCS-G 2 and LCS-G 3 cows.

More severely lame animals – less activity, no effect on rumination – indirect information about possible problems

New traits for breeding

- **Heat stress, resilience**
- **Feed efficiency / efficiency**
 - Measurements at test stations / test herds
 - Indirect traits for large-scale phenotyping
- **Methane and other environmental traits**
 - Greenfeed
 - Sniffer
 - MIR-Methane



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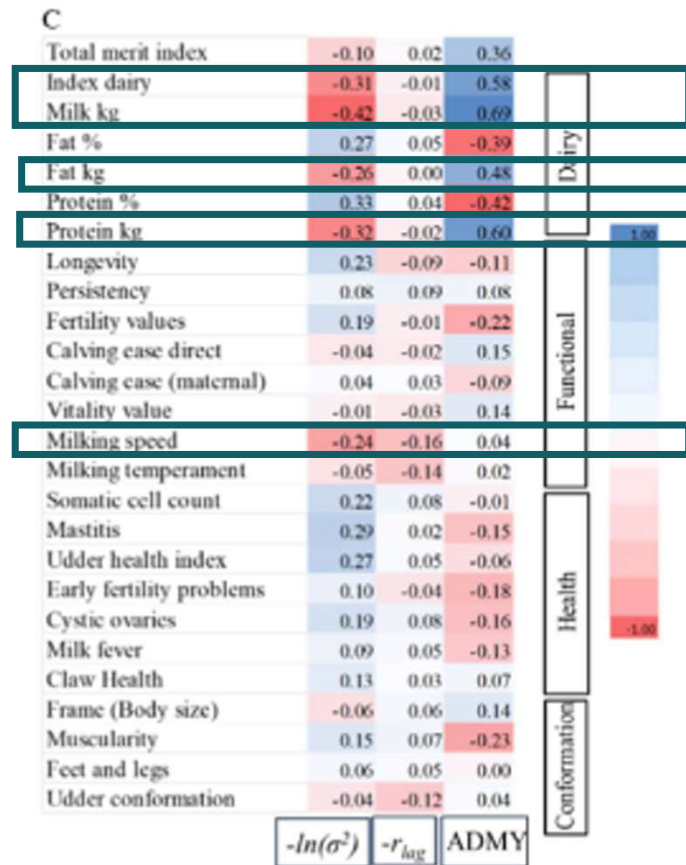


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Phenotypes?
Quality, quantity - cost?
Trade-offs?
Considerations?

Trade-offs and correlations with other traits



Analysing Resilience Indicator Traits in Austrian Fleckvieh, Brown Swiss and Holstein-Friesian Cattle

M. Agyiri¹ | R. Onzima^{1,2} | A. Costa³ | B. Fuerst-Waltl¹ | F. Steininger⁴ | C. Egger-Danner⁴ | G. Mészáros¹ | J. Sölkner¹

¹Universität für Bodenkultur Wien, Vienna, Austria | ²Muni University, Arua, Uganda | ³Alma Mater Studiorum Università di Bologna, Bologna, Italy | ⁴ZuchtData EDV-Dienstleistungen GmbH, Vienna, Austria

Correspondence: G. Mészáros (gabor.meszaros@boku.ac.at)

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Resilience indicator traits from Lactation curve models

Negative correlations between milk production traits and resilience.

FIGURE 2 | Correlations of resilience indicators and ADMY with selection index traits in FI, from full lactations using WC (A), QS (B) and CS (C), with positive correlations colour coded as blue and negative correlations as red. [Colour figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.com)]

Reducing methane emissions – are there potential trade-offs?



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Prediction of methane emissions in Austrian dairy cows using milk mid-infrared spectra and milk fatty acids: a nested cross-validation approach

A. Köck,^{1*} K. Linke,¹ C. Schmid,² F. J. Auer,² M. Mayerhofer,¹ J. Sölkner,³ T. Guggenberger,⁴ A. Steinwider,⁴ and C. Egger-Danner¹

¹ZuchtData EDV-Dienstleistungen GmbH, Dresdner Str. 89/18, 1200 Vienna, Austria

²LKV Austria, Dresdner Str. 89/18, 1200 Vienna, Austria

³University of Natural Resources and Life Sciences, Vienna (BOKU), Department of Agricultural Sciences, Institute of Livestock Sciences, Gregor-Mendel-Str. 33, 1150 Vienna, Austria

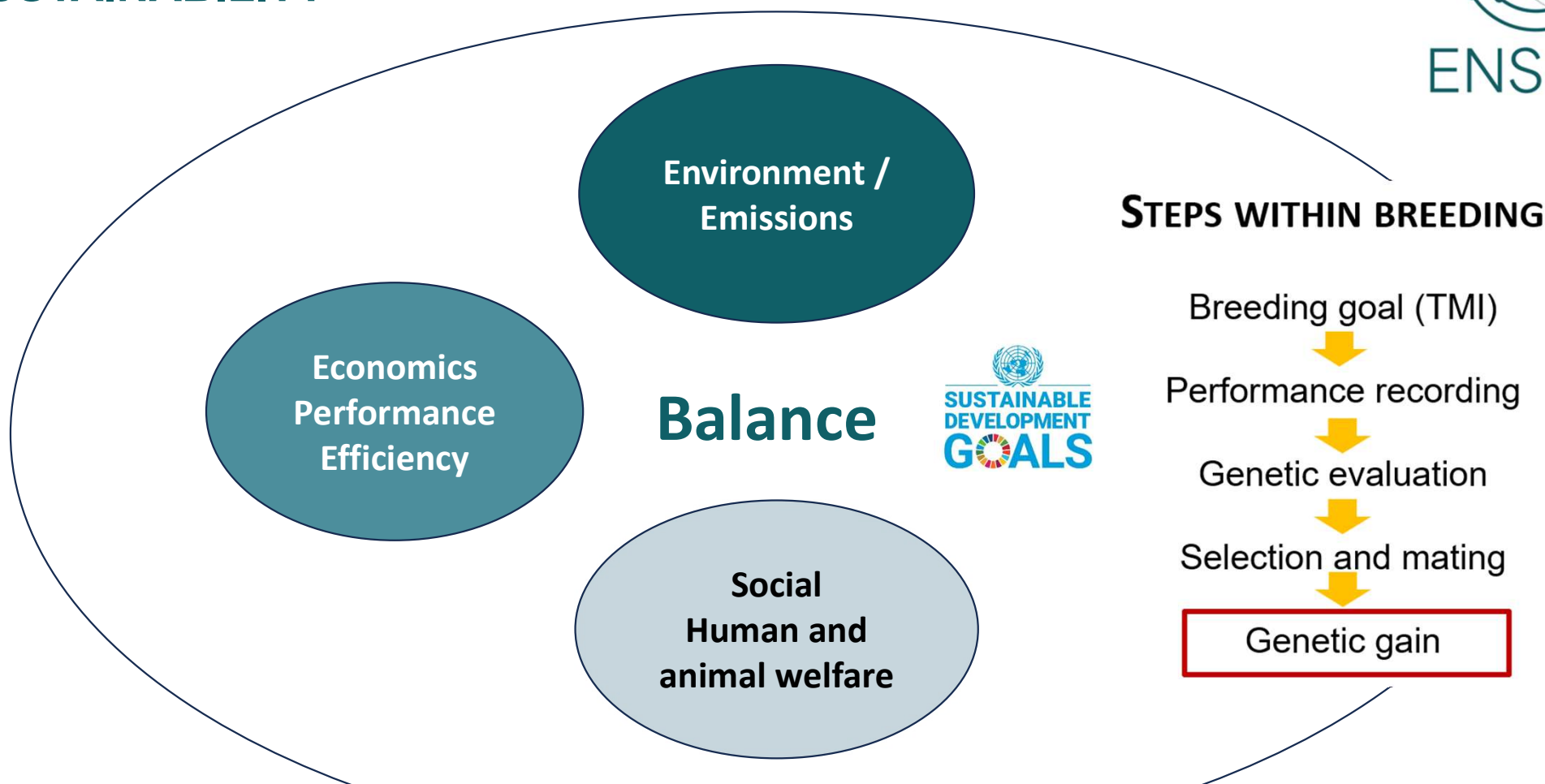
⁴Agricultural Research and Education Center Raumberg-Gumpenstein, Raumberg 38, 8952 Irnding-Donnersbachtal, Austria

-0.25	0.26	0.41	0.48	0.15	0.03	0.29	0.47	0.34	0.22	0.10	0.07	0.73	0.26	0.13	0.02	0.16	0.42	-0.07	0.47	0.22	0.55	0.55	0.28	0.58	C14:0
-0.10	0.03	0.48	0.47	0.12	0.11	0.37	0.29	0.12	-0.01	-0.20	-0.07	0.45	0.10	0.20	-0.08	0.13	-0.04	0.06	0.28	0.29	0.44	0.56	0.44	0.42	C16:0
0.05	-0.42	-0.17	-0.30	-0.18	0.05	0.03	-0.18	0.13	-0.09	-0.26	-0.46	-0.55	-0.09	0.13	0.03	-0.32	-0.14	0.04	-0.52	0.02	-0.50	-0.07	-0.28	-0.48	C16:1 cis-9
0.21	-0.10	-0.33	-0.36	0.01	0.02	-0.47	-0.28	-0.48	-0.12	-0.37	-0.23	-0.64	-0.17	-0.33	-0.14	0.10	-0.31	-0.11	0.31	-0.24	-0.33	-0.47	-0.20	-0.44	C18:0
0.04	-0.23	-0.47	-0.46	-0.09	0.05	-0.27	-0.36	-0.43	-0.11	-0.20	-0.44	-0.69	-0.24	-0.16	-0.07	-0.34	-0.26	0.10	-0.31	-0.16	-0.56	-0.55	-0.35	-0.79	C18:1 cis-9
0.19	-0.26	-0.42	-0.55	0.05	0.12	-0.19	-0.36	-0.51	-0.18	-0.42	-0.40	-0.61	-0.32	-0.19	-0.26	-0.32	-0.24	-0.04	-0.48	-0.38	-0.58	-0.53	-0.40	-0.64	C18:1 cis-11
-0.34	-0.18	-0.45	-0.34	0.20	0.19	-0.18	-0.07	-0.31	-0.10	-0.13	-0.35	-0.62	0.09	-0.09	-0.16	-0.40	0.09	-0.02	-0.16	0.08	-0.37	-0.47	-0.28	-0.28	C18:2 cis-9, cis-12
-0.11	0.11	-0.26	-0.08	-0.08	-0.01	-0.22	0.17	-0.08	0.06	-0.04	-0.03	-0.46	-0.16	-0.07	0.03	-0.12	0.08	0.02	0.40	-0.07	0.02	-0.11	-0.12	0.01	C18:3 cis-9, cis-12, cis-15
0.16	0.18	0.04	0.11	-0.52	-0.29	0.05	0.21	0.22	0.01	-0.17	0.15	0.10	-0.25	0.10	0.10	0.01	0.04	0.10	0.00	-0.24	-0.05	0.14	-0.12	0.02	C18:2 cis-9, trans-11
Farm 1.1	Farm 1.2	Farm 2.1	Farm 2.2	Farm 3.1	Farm 3.2	Farm 4.1	Farm 4.2	Farm 5.1	Farm 5.2	Farm 6.1	Farm 6.2	Farm 7.2	Farm 8.1	Farm 8.2	Farm 9.1	Farm 9.2	Farm 10.1	Farm 10.2	Farm 11.1	Farm 12.1	Farm 13.1	Farm 14.1	Farm 15.1	Farm 16.1	

Phenotypic associations between methane and milk fatty acids on 16 dairy farms

- Lower methane emissions may affect **energy metabolism, body reserves, health and fertility**
- Further research on **correlated selection responses** is needed.

ENSURE BETTER BREEDING TO ENHANCE RESILIENCE AND SUSTAINABILITY



Research: Optimisation of phenotyping strategies related to different dimensions of sustainability.

Methods and approaches

- **Define potential „direct“ and „indirect“ traits**
- **Assess potential of different types of phenotypes**
 - Different trait definitions
 - Genetic background (heritabilities, correlations to target traits)
 - Number of potential phenotypes (combination with genotypes)
 - Costs of phenotyping
- **Develop different phenotyping strategies and evaluate**
 - Estimate reliabilities of expected breeding values – stochastic simulations
 - Expected monetary genetic gain and costs - ZPLAN deterministic simulation
 - Derive estimates for production and functional traits and methane emissions

Derive recommendations for breeding organisations to develop breeding strategies towards increased sustainability!

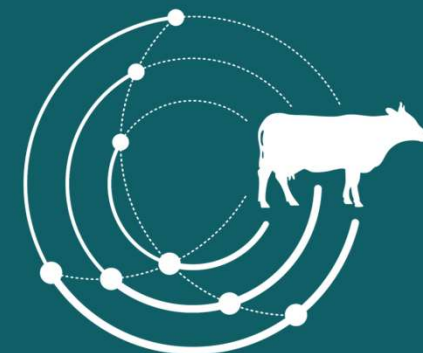
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Data driven strategies to enhance sustainability, resilience, and resource efficiency of cattle farming

1.11.2025 - 30.04.2029