EAAP 2016
67th Annual Meeting of the European Federation of Animal Science
Belfast UK, 29 Aug – 2 Sept 2016

Genetic correlations of fighting ability with udder health and longevity in Valdostana cattle

C. Sartori, N. Guzzo, R. Mantovani
University of Padua, Department of Agronomy, Food, Natural Resources, Animals and Environment

Introduction: The costs of fighting

DAFNAE
Department of Agronomy Food
Natural Resources Animals Environment

Life-history theory

Trade-off between investment in **competition** (e.g., for mating, for food) and fitness → fertility & **survival** (longevity, immuno-resistence) (e.g., Roff et al., 2002)

Due to **functional constraints** in potentially beneficial traits that often occur (Lessel et al., 2008)

ENERGY COSTS

DIFFERENT ALLOCATION

Introduction: The costs of fighting

DAFNAE
Department of Agronomy Food Natural Resources Animals Environment

Trade-offs

Fighting for reproduction vs. survival (immune response to parasites)

Bank vole, *Myodes glareolus*

Mills et al., 2009, Evolution

High competitive success of fathers vs. low fitness (survival) of daughters

Red deer (Cervus elaphus)

Foerster et al., 2007, Nature

Male attractiveness (coloration) vs. survival (no. sons maturing): negative genetic correlations

Guppy (*Poecilia reticulata*)

Brooks, 2000, Nature

Competitive ability for food vs. parasitoid resistance

Larvae of *D. melanogaster*

Kraaijeveld & Godfray, *1997, Nature*

Alleles of RXFP2 gene:
Ho^1: larger horns →higher reproductive success;
Ho^P: smaller horns, increased survival

Soay sheep (Ovis aries)

Johnston et al., 2013, Nature

Introduction: Trade-offs in cattle

DAFNAE
Department of Agronomy Food Natural Resources Animals Environment

FERTILITY (Pryce et al., 2004)

MILK YIELD

LONGEVITY
(mean no. calving; Knaus, 2009)

UDDER HEALTH
(rev. Oltenacu & Broom, 2010)

r_a around 0.14

r_a from 0.24 to 0.68

SOMATIC CELL SCORE (SCS)
(Mrode & Swanson, 1996; Pryce & Brotherstone, 1999); Rupp & Boichard, 1999)

CLINICAL MASTITS
(Pryce et al., 1998; Rupp & Boichard, 1999; Heringstad et al., 2000; Kadarmideen et al., 2000; Ingvartsen et al. 2003)

Aim of the study

DAFNAE
Department of Agronomy Food
Natural Resources Animals Environment

✓To investigate the genetic relationships of **fighting ability** with **udder health** traits and **longevity**

✓*To establish if fighting ability is costly in terms of immune functions and longevity at genetic level*

Materials & Methods

DAFNAE
Department of Agronomy Food Natural Resources Animals Environment

Fighting Ability

✓ Capability to win a contest (Parker, 1974)

✓ Important role at pasture: cows establish firm dominance relations when unfamiliar individuals meet (Beilharz & Zeeb, 1982)

Aosta Chestnut & Aosta Black Pied cattle (Valdostana breed)

✓ Native of West Alps, same herd book
✓ 2014: 211 breeding males & 5594 females
✓ Triple attitude (2012): milk, meat, fight
✓ Milk: 2345 kg/year, 3.47% fat, 3.39% protein
✓ Meat: linear type traits for muscularity
✓ Strong attitude to fight: *"Batailles de Reines"*

“Batailles de Reines”

DAFNAE
Department of Agronomy Food
Natural Resources Animals Environment

“Batailles de Reines”

DAFNAE
Department of Agronomy Food Natural Resources Animals Environment

- ✓ 20 heats + final fight
- ✓ 200-300 participants/day
- ✓ 3 tournaments/day, by weight categories
- ✓ Knock-out battles among pairs of cows
- ✓ Only Aosta Chestnut & Aosta Black Pied cattle
- ✓ Check for milking & pregnancy to participate
- ✓ Winners: “Queens”, great economic value

Sartori & Mantovani 2010, 2012 J Anim Sci; Sartori & Mantovani 2012 Heredity; Sartori et al., 2014 Ital J Anim Sci; Sartori et al., 2015 Evolution

Datasets

- **Herd-book information** for Aosta Chestnut and Aosta black pied breeds
  (Updated at November 2015, provided by National Breeders Associations)
- **Phenotypic data** since year 2000:

Udder health

Test day milk

Fighting Ability

Longevity

Datasets

DAFNAE
Department of Agronomy Food Natural Resources Animals Environment

Fighting Ability

Phenotype

Placement Score (PS)

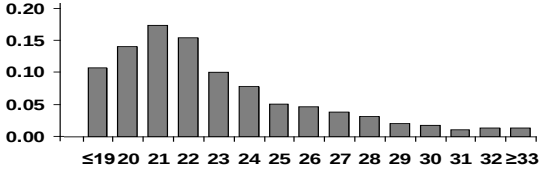
$$PS_{ijkl}=20+ty_i+d_j+2w_k$$

PS = score of cow in a given tournament

ty = type of tournament

d = difficulty coefficient dep. no no. participants

w = number of wins achieved



Genetic model

$$y = X\beta + Wp + Zu + e$$

✓ **Fixed effects (β):**
Year-Battle-Category,
Herd-year, Age (class),
Weight (class)

✓ **Random effects (p, u, e):**
Permanent environment,
Additive genetic,
Residual

✓Weekly collected at “Batailles de Reines” (March - October)

✓ Continuous (18-41) point scale

31,894 records; 9,328 cows; 19,283 animals in pedigree

Sartori & Mantovani, 2010, J Anim Sci

Datasets

DAFNAE
Department of Agronomy Food
Natural Resources Animals Environment

Udder health

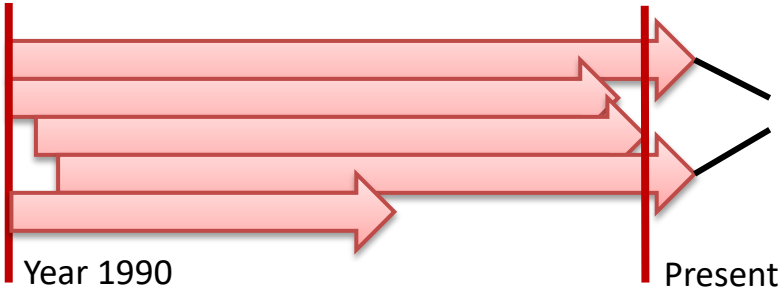
Test day milk

Fighting Ability

Longevity

Datasets

Phenotype



Genetic model

$$y = X\beta + Zu + e$$

✓ **Fixed effects (β):**
Herd-year, age (class),
Milk production (class)

✓ **Random effects (u, e):**
Additive genetic,
Residual

Longevity

✓Length of **productive life** from the first calving (years, continuous scale);
✓**Number of calving** (no., discrete scale);
✓Achieved from pedigree for the same cows with fighting ability data

9,328 single records for cows; 19,283 animals in pedigree

Datasets

DAFNAE
Department of Agronomy Food
Natural Resources Animals Environment

Udder health

Test day milk

Fighting Ability

Longevity

Datasets

DAFNAE
Department of Agronomy Food Natural Resources Animals Environment

Phenotype

- ✓ Udder health valued as **Somatic cells score** & **SC150**
- ✓ Individual test day records of **milk** (kg)
- ✓ Evaluated in routinely test-day controls

23,522 records; 6,202 cows; 15,144 animals in pedigree

Somatic cell score:

$$SCS = 3 + (\log2(SCC / 100 \cdot 10^3))$$

SCC = somatic cells count
Normal distribution

SC150:

$$SC150 = SCC > 150 \cdot 10^3 cells/ml$$

Threshold trait for the occurrence of pathological mastitis

Udder health

Test day milk

Genetic model

Repeatability Test-Day model (Meyer, 1995; Mazza et al., 2016)

$$y = X\beta + Wp + Zu + e$$

✓ **Fixed effects (β):**
Herd-test-day within lactation no., Parity class, Age at parity classes within lact., Month of parity (classes), 4th order Legendre polynomials (Straber & Misztal, 1999)

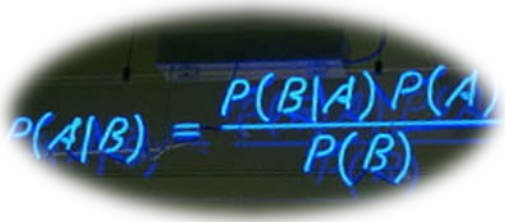
✓ **Random effects (p, u, e):**
Permanent environment, Additive genetic, Residual

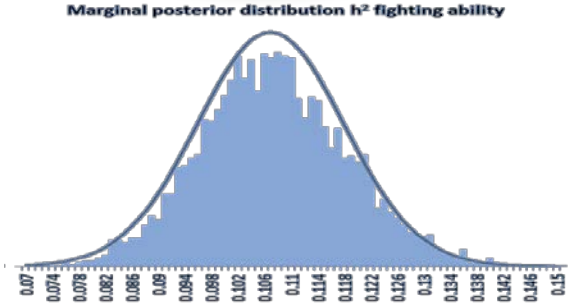
Genetic analyses

- Bayesian inference, **Gibbs sampling** algorithm (Gelfand and Smith, 1990)
- **Flat priors** for systematic and random effects;
- Chain of 480,000 samples, burn-in of 30,000 samples, every 150-th iterations saved

- **Linear traits**: GIBBS3F90 program (Misztal et al., 2008)
  - Fighting ability, SCS, Milk;
- **Threshold traits**: THRGIBBS1F90 program (Tsuruta & Misztal, 2006)
  - SC150;
- **Linear censored traits**: GIBBS2CEN program (Arango et al., 2005)
  - Productive life, No. calvings;

✓ *Preliminary single-traits analyses;*
✓ *Bi-trait analyses among trait pairs;*





$$\mathrm{Var}\begin{vmatrix} a_1 \\ a_2 \end{vmatrix} = \begin{vmatrix} A\sigma^2_{a1} & A\sigma_{a1\,a2} \\ A\sigma_{a1\,a2} & A\sigma^2_{a2} \end{vmatrix};$$

$$\mathrm{Var}\begin{vmatrix} pe_1 \\ pe_2 \end{vmatrix} = \begin{vmatrix} I\sigma^2_{pe1} & I\sigma_{pe1\,pe2} \\ I\sigma_{pe1pe2} & I\sigma^2_{pe2} \end{vmatrix};$$

$$\mathrm{Var}\begin{vmatrix} e_1 \\ e_2 \end{vmatrix} = \begin{vmatrix} I\sigma^2_{e1} & 0/I\sigma_{e1\,e2} \\ 0/I\sigma_{e1\,e2} & I\sigma^2_{e2} \end{vmatrix};$$

Results

DAFNAE
Department of Agronomy Food
Natural Resources Animals Environment

Results

DAFNAE
Department of Agronomy Food Natural Resources Animals Environment

	Phenotypic Mean (SD)	*Single traits variance components*[1]			
		σ^2_{Pe}	σ^2_a	σ^2_e	h^2
Fighting ability (points)	*23.2 (3.39)*	0.94 (0.77 1.12)	0.83 (0.66 1.00)	5.98 (5.86 6.10)	**0.11** (0.09 0.13)
Productive life (years)	*4.46 (2.07)*		0.71 (0.54 0.87)	2.02 (1.86 2.18)	**0.26** (0.20 0.32)
No. parities	*4.30 (1.94)*		0.54 (0.39 0.68)	1.95 (1.8 2.09)	**0.22** (0.16 0.27)
SCS (points)	*2.19 (1.87)*	0.84 (0.71 0.96)	0.18 (0.06 0.29)	1.85 (1.8 1.90)	**0.06** (0.02 0.10)
SC150 (points)[2]	*1.21 (0.41)*	1.00 (0.72 1.28)	0.43 (0.18 0.69)	1.07 (1.04 1.10)	**0.17** (0.07 0.27)
Milk (kg/day)	*6.32 (2.02)*	0.90 (0.77 1.03)	0.45 (0.3 0.60)	0.63 (0.61 0.65)	**0.23** (0.16 0.30)

[1]Posterior means of the gibbs samples; lower and upper bounds of the 95% highest posterior density region in brackets;
[2]Expressed in liability scale

Correlations among traits

DAFNAE
Department of Agronomy Food Natural Resources Animals Environment

	Fighting ability	Prod. life	No. calvings	SCS	CS150	Milk
Fighting ability		**0.89** *(0.78 1.01)*	**0.77** *(0.62 0.92)*	**0.26** *(0.01 0.49)*	**0.29** *(0.02 0.58)*	-0.13 *(-0.33 0.06)*

High & positive genetic correlations (r_a) for fighting ability & longevity traits

- Productive life of cows strictly related to their competitive ability in traditional tournaments
- Cultural & economic importance for farmers:
- Difficult to disentangle the positive effect of the economic worth of fighting ability and its potential negative implications for fitness

Positive r_a between fighting ability & somatic cells

- Increment of somatic cells → detriment of udder health
- Consistent with expected life-history trade-offs:
- Greater competitive ability joined to lessened immune functions

Low negative r_a with test-day milk

- Posterior means include zero, but previous r_a considering the whole lactations (Sartori et al., 2015) were more negative (-0.19)

Correlations among traits

	Fighting ability	Prod. life	No. calvings	SCS	CS150	Milk
Fighting ability						
Prod. life						
No. calvings						
SCS				-0.15 *(-0.62 0.32)*	-0.34 *(-0.78 0.10)*	**-0.44** ***(-0.73 -0.15)***
SC150				-0.18 *(-0.65 0.29)*	-0.28 *(-0.68 0.11)*	**-0.47** ***(-0.76 -0.19)***
Milk						**-0.41** ***(-0.72 -0.10)***
						-0.28 *(-0.62 0.05)*

Slight negative genetic correlations (r_a) for longevity & somatic cells

- Suggest (they include zero) a positive relation between udder health & productive life

Negative r_a milk vs. longevity

- Confirm the well known trade-off in cattle genetic literature

Negative r_a milk vs. somatic cells

- Greater fighting → reduced milk yield → increased somatic cells

Correlations among traits

DAFNAE
Department of Agronomy Food Natural Resources Animals Environment

	Fighting ability	Prod. life	No. calvings	SCS	CS150	Milk
Fighting ability		**0.89** ***(0.78 1.01)***	**0.77** ***(0.62 0.92)***	**0.26** ***(0.01 0.49)***	**0.29** ***(0.02 0.58)***	-0.13 *(-0.33 0.06)*
Prod. life			**0.99** ***(0.99 1.00)***	-0.15 *(-0.62 0.32)*	-0.34 *(-0.78 0.10)*	**-0.44** ***(-0.73 -0.15)***
No. calvings				-0.18 *(-0.65 0.29)*	-0.28 *(-0.68 0.11)*	**-0.47** ***(-0.76 -0.19)***
SCS					**0.99** ***(0.99 1.00)***	**-0.41** ***(-0.72 -0.10)***
SC150						-0.28 *(-0.62 0.05)*
Milk						

Genetic correlations

Correlations among traits

DAFNAE
Department of Agronomy Food Natural Resources Animals Environment

	Fighting ability	Prod. life	No. calvings	SCS	CS150	Milk
Fighting ability		**0.89** ***(0.78 1.01)***	**0.77** ***(0.62 0.92)***	**0.26** ***(0.01 0.49)***	**0.29** ***(0.02 0.58)***	-0.13 *(-0.33 0.06)*
Prod. life	**0.22** ***(0.19 0.24)***		**0.99** ***(0.99 1.00)***	-0.15 *(-0.62 0.32)*	-0.34 *(-0.78 0.10)*	**-0.44** ***(-0.73 -0.15)***
No. calvings	**0.14** ***(0.11 0.16)***	**0.86** ***(0.85 0.87)***		-0.18 *(-0.65 0.29)*	-0.28 *(-0.68 0.11)*	**-0.47** ***(-0.76 -0.19)***
SCS	0.01 *(-0.01 0.03)*	-0.01 *(-0.07 0.05)*	-0.02 (-0.08 0.03)		**0.99** ***(0.99 1.00)***	**-0.41** ***(-0.72 -0.10)***
SC150	0.02 *(-0.01 0.04)*	-0.01 *(-0.04 0.02)*	-0.02 (-0.05 0.01)	**0.99** ***(0.99 1.00)***		-0.28 *(-0.62 0.05)*
Milk	<-0.01 *(-0.02 0.01)*	**-0.27** ***(-0.33 -0.21)***	**-0.25** ***(-0.31 -0.19)***	**-0.17** ***(-0.19 -0.15)***	**-0.20** ***(-0.24 -0.17)***	

Genetic correlations

Phenotypic correlations

Previous correlation estimates

DAFNAE
Department of Agronomy Food Natural Resources Animals Environment

doi:10.1111/evo.12723

Evolution of increased competitiveness in cows trades off with reduced milk yield, fertility and more masculine morphology

Cristina Sartori,[1,2] Serena Mazza,[1,*] Nadia Guzzo,[1,*] and Roberto Mantovani[1]
[1]Department of Agronomy, Food, Natural Resources, Animals and Environment—DAFNAE, University of Padua, Viale dell'Universita', 16, 35020 Legnaro, PD, Italy

EVOLUTION AUGUST 2015

	r_a		r_P	
Trait (unit of measure; Abbrev.)	Value	P_z	Value	P_z
Milk yield traits (kg/100; MY)				
Milk	−0.196 (0.088)	**0.006**	−0.017 (0.009)	**0.015**
Fat	−0.124 (0.089)	**0.041**	−0.014 (0.009)	**0.030**
Protein	−0.161 (0.088)	**0.017**	−0.011 (0.009)	0.055
Fertility trait (months^{-1})				
Inverse of parity-conception interval (IPC)	−0.380 (0.173)	0.007	−0.053 (0.007)	**<0.001**
Morphological traits (points; MTs)				
Front muscularity	0.227 (0.153)	**0.035**	0.002 (0.013)	0.218
Thorax depth	0.269 (0.135)	**0.011**	0.010 (0.013)	0.118
Thinness	−0.264 (0.202)	**0.048**	−0.006 (0.013)	0.157
Udder	−0.309 (0.152)	**0.011**	−0.008 (0.013)	0.136
Fore udder attach	−0.162 (0.140)	0.061	0.021 (0.013)	**0.025**
Rear udder attach	−0.437 (0.138)	**<0.001**	−0.017 (0.013)	**0.047**
Udder width	−0.289 (0.143)	**0.011**	−0.030 (0.013)	**0.005**

Previous study:
Genetic **trade-off** of fighting ability with milk yield & **fertility**

More competitive females may suffer for a reduced fertility & are moving to a more masculine phenotype

Conclusions

DAFNAE
Department of Agronomy Food
Natural Resources Animals Environment

Conclusions

DAFNAE
Department of Agronomy Food Natural Resources Animals Environment

Trade-off

Competition (e.g., for mating, for food) ⟷ **Survival** (longevity, immuno-resistence)

Valdostana cattle → **Fighting ability**
(traditional cow competitions; h^2~0.10)

Longevity
(**productive life**, **no. calving**)

High-positive genetic correlations (r_a)
Productive life strictly related to competitive ability in traditional tournaments: the economic worth covers the eventual trade-offs

trade offs
(slight negative r_a)

Udder health
(**SCS, CS150**)

Positive r_a
Greater competitive ability joined to lessened immune functions:
trade-off consistent with expectations

How to deal with a genetic improvement for fighting attitude?

Necessity to account for functional, fitness-related traits

DAFNAE
Department of Agronomy Food
Natural Resources Animals Environment

THANKS FOR YOUR ATTENTION!

Acknowledgements

Coauthors:
Roberto Mantovani
Nadia Guzzo

AnaBoRaVa

Région Autonome Vallée d'Aoste
Regione Autonoma Valle d'Aosta

AREV

Association régionale
Amis des Batailles de Reines