

# Consideration of heat stress in multiple lactation test– day models for dairy production traits

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# Record processing

- Milk (M), Fat (F), Protein (P) (kg) and Somatic Cell Score (SCS): collected until May 2017 and calved after January 2000 in dairy farms, other than Hokkaido (an island in north of Japan)
- data editing criteria
  - Japanese National Genetic Evaluation
  - VCE: at least 10 cows within a farm – test–day – milking frequency (HTDT) and a farm – calving year – lactation (1st or 2nd + 3rd) (HYP) subclasses; then divided into 3 subsets randomly

- farms were linked to meteorological offices according to their locales for announcements regarding weather forecasts
- calculate Temperature-Humidity Index (THI) at meteorological offices

$$THI = (1.8 \times T_d + 32) - (0.55 - 0.0055 \times RH) \times (1.8 \times T_d - 26)$$

$T_d$ : dry bulb temperature (Celsius),  $RH$ : relative humidity (%)

- each phenotype was linked to the average THI on 2 - 4 (M, F, P) / 1-12 (SCS) days before test day
- Heat stress: change of phenotypes at  $THI > THI_{\text{threshold}}$

# Random regression test day model

Difference with National model

$$y_{ijklmno} = HTDT_i + \mathbf{M}'_j \mathbf{w} + \mathbf{Ag}'_k \mathbf{w} + \mathbf{hyp}'_l \mathbf{v} + \mathbf{pe}'_{mn} \mathbf{z} + \boxed{peh_{mn} \cdot f(THI)} + \mathbf{u}'_{mn} \mathbf{z} + \boxed{uh_{mn} \cdot f(THI)} + e_{ijklmno}$$

•  $y_{ijklmno}$ : M / F / P (kg), SCS, pre-adjusted for expected amount of decrease / increase corresponding to THI **New!**

•  $HTDT_i$ : fixed effect of herd\*test day\*milking frequency

•  $\mathbf{M}_j$ : fixed regression coefficients of calving month

•  $\mathbf{Ag}_k$ : fixed regression coefficients of calving age\*lactation

•  $\mathbf{hyp}_l$ : random regression coefficients of herd\*calving year \*lactation (1 or 2+3) effects

•  $\mathbf{pe}_{mn}$ : random regression coefficients of general permanent environment (PE) effects \* lactation

•  $peh_{mn}$ : random linear regression coefficient of PE effect of heat tolerance \* lactation

•  $\mathbf{u}_{mn}$ : random regression coefficients of general additive genetic (AG) effects \* lactation

•  $uh_{mn}$ : random linear regression coefficient of AG effects of heat tolerance \* lactation

•  $e_{ijklmno}$ : random residuals at days in milk (DIM: 6-35, 36-65, 66-95, 96-125, 126-215, 216-305) \* lactation

•  $\mathbf{w}' = [\phi_0(t) \ \phi_1(t) \ \phi_2(t) \ \phi_3(t) \ \phi_4(t) \ e^{-0.05t}]$ ,  $\mathbf{v}' = [\phi_0(t) \ \phi_1(t)]$ ,  $\mathbf{z}' = [\phi_0(t) \ \phi_1(t) \ \phi_2(t)]$

•  $\phi_p(t)$ : Legendre polynomials, t = DIM

•  $f(THI) = \begin{cases} 0 & \text{if } THI \leq THI_{threshold} \\ THI - THI_{threshold} & \text{if } THI \geq THI_{threshold} \end{cases}$

• Not the case for F / P (kg) in the previous study (AAAP2018, Kuching, Malaysia)

• VCE failed

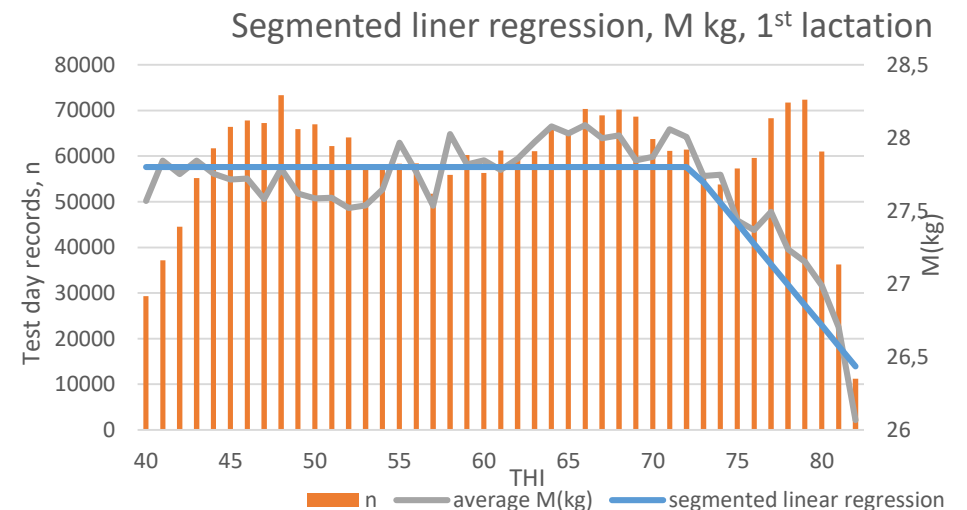
# THI<sub>thresholds</sub> and change per 1 THI (from the previous study)

Traits	Lactation	Test day records, n	THI <sub>threshold</sub>			change / 1 THI		
			M	F	P	M	F	P
M, F, P	1 <sup>st</sup>	8,983,199	72.246	54.356	66.008	-8.19e-2	-3.27e-3	-3.54e-3
	2 <sup>nd</sup>	7,448,202	71.886	53.444	64.368	-1.72e-1	-4.25e-3	-5.01e-3
	3 <sup>rd</sup>	5,316,403	66.521	51.167	58.788	-1.59e-1	-5.01e-3	-4.62e-3
SCS	1 <sup>st</sup>	7,690,035		63.645			1.73e-2	
	2 <sup>nd</sup>	6,361,339		64.865			1.24e-2	
	3 <sup>rd</sup>	4,509,975		59.460			1.26e-2	

- Segmented linear regression analysis (R segmented package)

$$y_i = c + e_i; \text{ when } THI_i < THI_{\text{threshold}}$$

$$y_i = a + b * THI_i + e_i; \text{ when } THI_i > THI_{\text{threshold}}$$



# Summary of records

	Traits							
	milk, fat, protein (kg)				SCS			
	Set1	Set2	Set3	Full	Set1	Set2	Set3	Full
<b>test-day records</b>	1,456,561	1,443,028	1,570,143	13,460,744	1,454,642	1,559,421	1,332,148	13,098,209
<b>cows (female with records)</b>	79,705	78,337	85,110	722,170	80,207	86,527	73,838	714,212
<b>bulls (sire of cows)</b>	4,621	4,621	4,697	7,311	4,594	4,746	4,495	7,283
<b>other animals in a pedigree</b>	112,989	105,790	109,366	663,971	107,365	113,377	106,814	660,627

# Covariance components

$$\text{var} \begin{bmatrix} \mathit{hypt} \\ \mathit{pet} \\ \mathit{ut} \\ \mathit{e} \end{bmatrix} = \begin{bmatrix} \mathbf{I} \otimes \mathbf{Q} & \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{I} \otimes \mathbf{P} & \mathbf{0} & \mathbf{0} \\ & & \mathbf{A} \otimes \mathbf{U} & \mathbf{0} \\ \mathit{sym.} & & \mathbf{0} & \mathbf{R} \end{bmatrix}$$

Estimated by gibbs3f90,  
BLUPF90 family

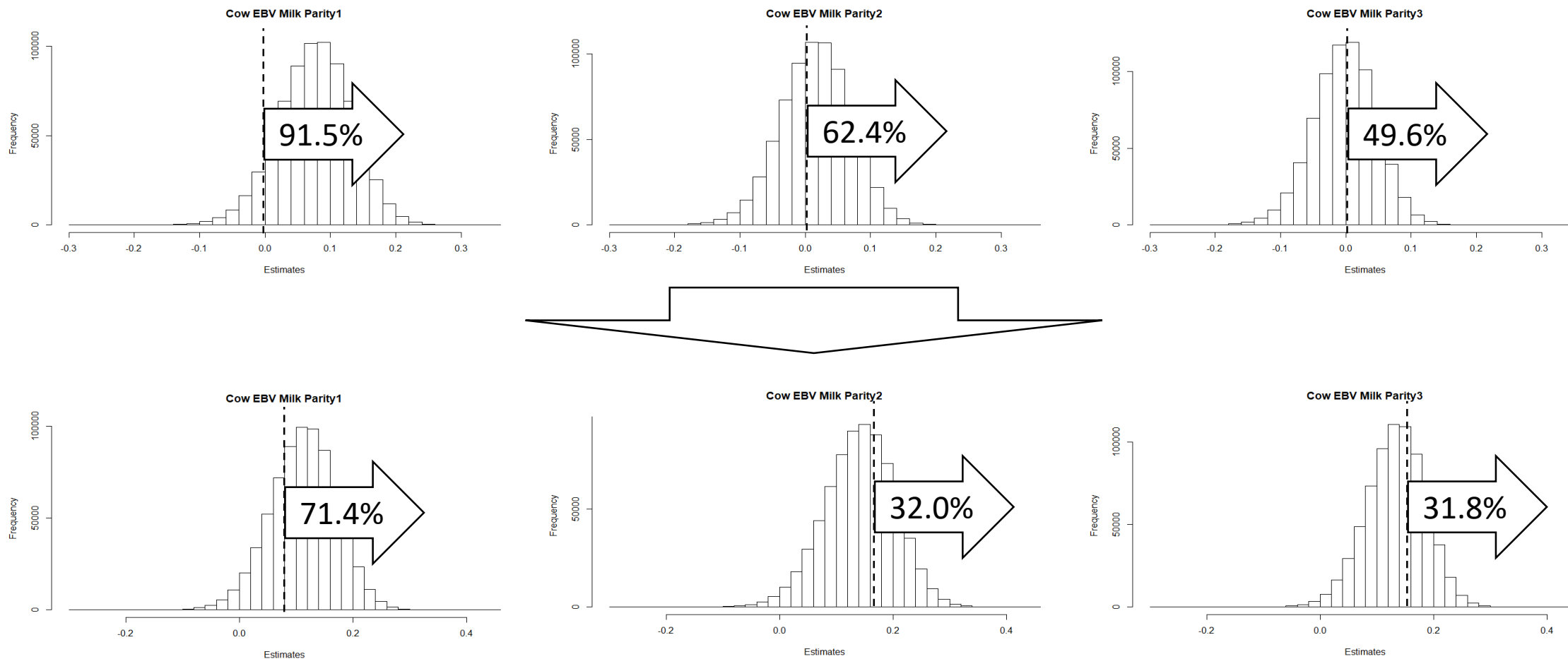
- $\mathit{hypt}' = [\mathit{hyp}'_1 \quad \dots \quad \mathit{hyp}'_l \quad \dots]$
- $\mathit{pet}' = [\mathit{pe}'_{11} \quad \mathit{peh}_{11} \quad \mathit{pe}'_{12} \quad \mathit{peh}_{12} \quad \mathit{pe}'_{13} \quad \mathit{peh}_{13} \quad \dots \quad \mathit{pe}'_{mn} \quad \mathit{peh}_{mn} \quad \dots]$
- $\mathit{ut}' = [\mathit{u}'_{11} \quad \mathit{uh}_{11} \quad \mathit{u}'_{12} \quad \mathit{uh}_{12} \quad \mathit{u}'_{13} \quad \mathit{uh}_{13} \quad \dots \quad \mathit{u}'_{mn} \quad \mathit{uh}_{mn} \quad \dots]$
- $\mathit{e}' = [e_1 \quad \dots \quad e_{ijklmno} \quad \dots]$
- $\mathbf{I}$  : identity matrix
- $\mathbf{Q}$  : 2×2 matrix of (co)variances for hyp effects (2×2)
- $\mathbf{A}$  : numerator relationship matrix
- $\mathbf{P}, \mathbf{U}$  : 12 (3 regression coefficients of Legendre polynomials for the general effects + 1 regression coefficient for HT) × 3 × 12 matrices of (co)variances for PE and AG effects
- $\mathbf{R}$  : diagonal matrix with residual variance corresponding to DIM in n<sup>th</sup> lactation category

# Heritabilities at THI=80

traits	lactation	total		heat tolerance	
		previous study	present study	previous study	present study
milk (kg)	1 <sup>st</sup>	0.2831±0.0063	0.2798±0.0062	0.0294±0.0014	0.0298±0.0013
	2 <sup>nd</sup>	0.2427±0.0055	0.2435±0.0056	0.0167±0.0008	0.0220±0.0010
	3 <sup>rd</sup>	0.2050±0.0070	0.2143±0.0071	0.0372±0.0019	0.0434±0.0021
fat (kg)	1 <sup>st</sup>	0.2013±0.0047	0.2148±0.0050	0.0311±0.0015	0.0254±0.0015
	2 <sup>nd</sup>	0.1962±0.0042	0.1941±0.0049	0.0191±0.0009	0.0445±0.0025
	3 <sup>rd</sup>	0.1942±0.0048	0.2053±0.0060	0.0188±0.0009	0.0459±0.0024
protein (kg)	1 <sup>st</sup>	0.2278±0.0055	0.2312±0.0077	0.0337±0.0014	0.0357±0.0050
	2 <sup>nd</sup>	0.2081±0.0053	0.2078±0.0076	0.0249±0.0011	0.0403±0.0061
	3 <sup>rd</sup>	0.2015±0.0060	0.2048±0.0085	0.0384±0.0016	0.0463±0.0063
SCS	1 <sup>st</sup>	0.1281±0.0041	0.1277±0.0041	0.0088±0.0007	0.0088±0.0008
	2 <sup>nd</sup>	0.2081±0.0053	0.1553±0.0041	0.0089±0.0005	0.0092±0.0006
	3 <sup>rd</sup>	0.2015±0.0060	0.1878±0.0060	0.0180±0.0013	0.0194±0.0013

- Generally, heritabilities of HT increased in the present study

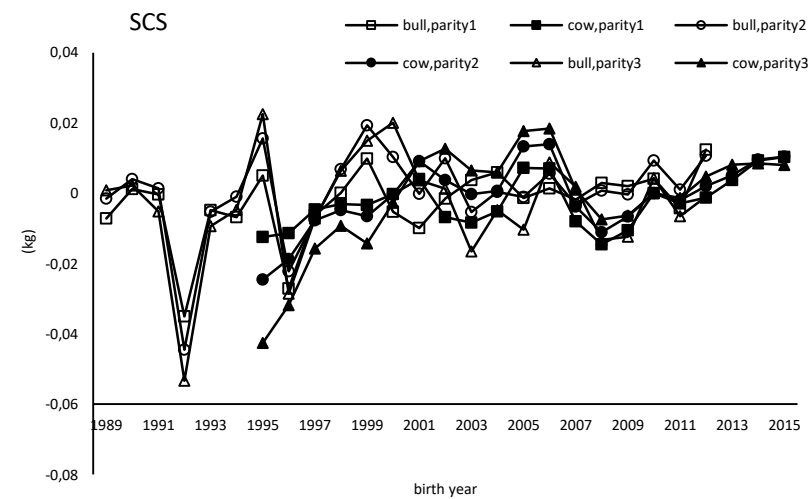
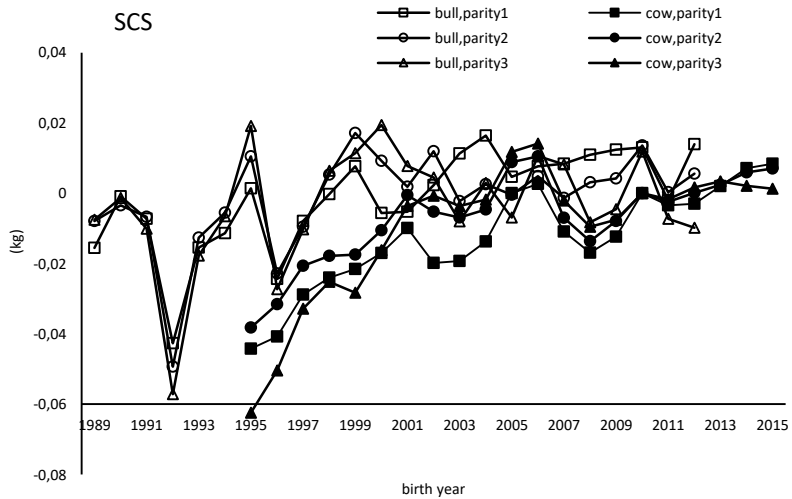
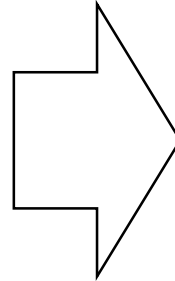
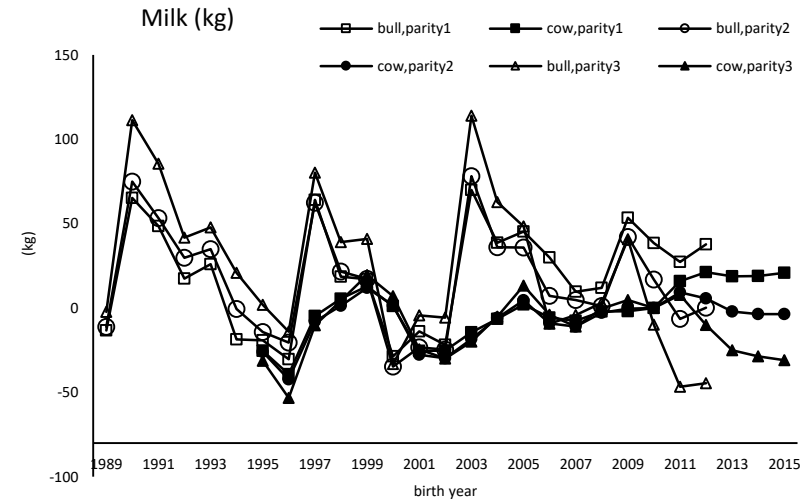
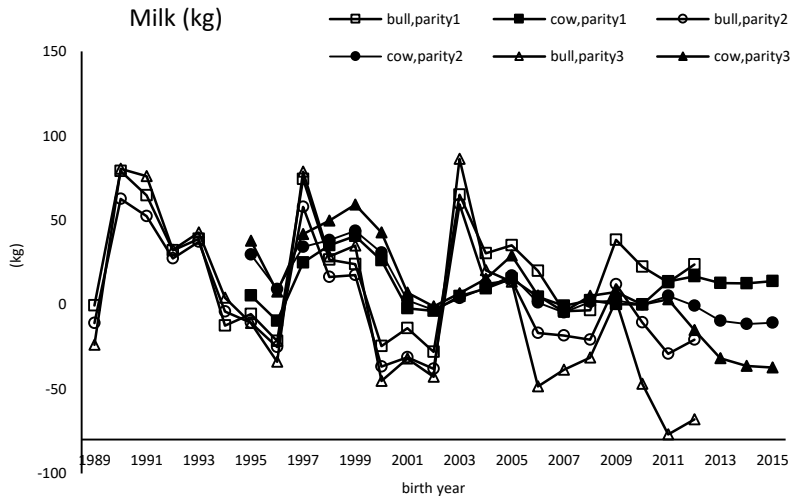
# Distributions of the estimates of AG effects of HT, milk(kg)



- above: the previous study, below: the present study
- better results in the present study, also for other traits

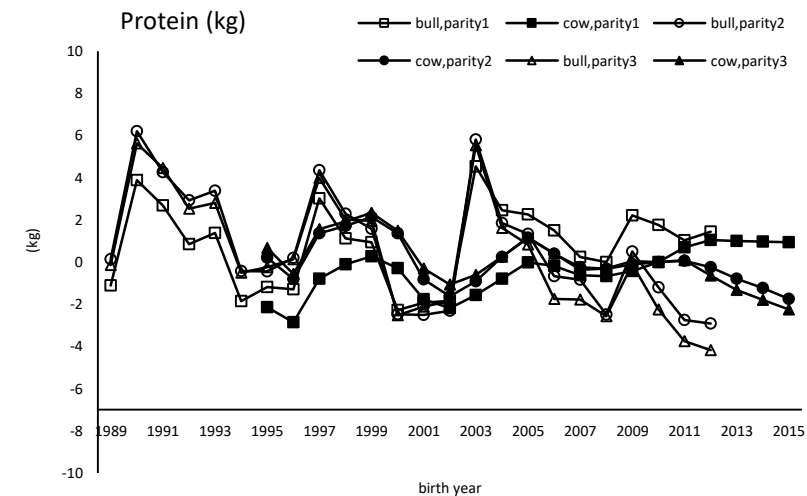
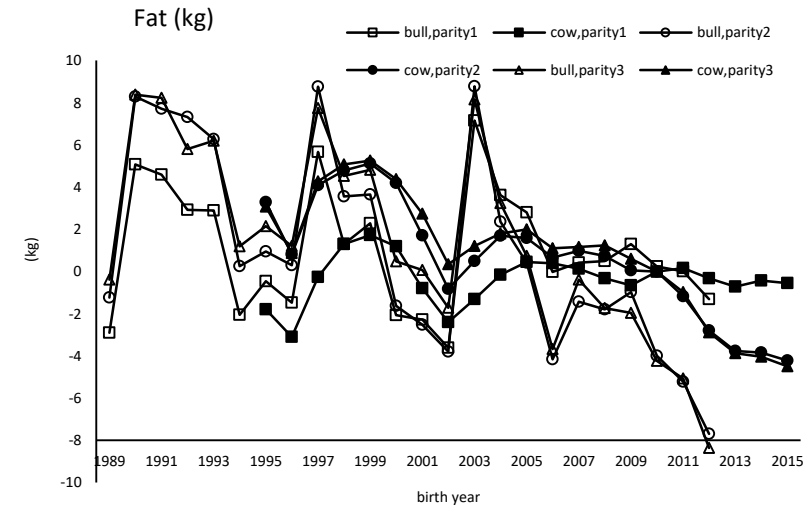
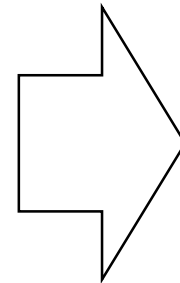
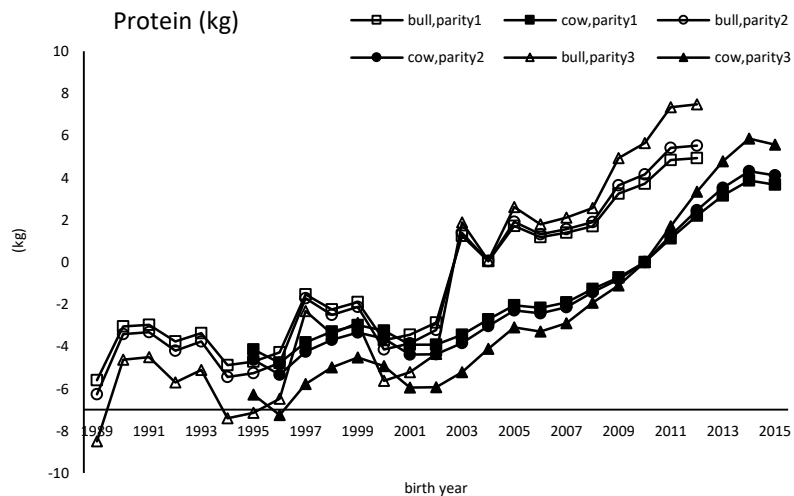
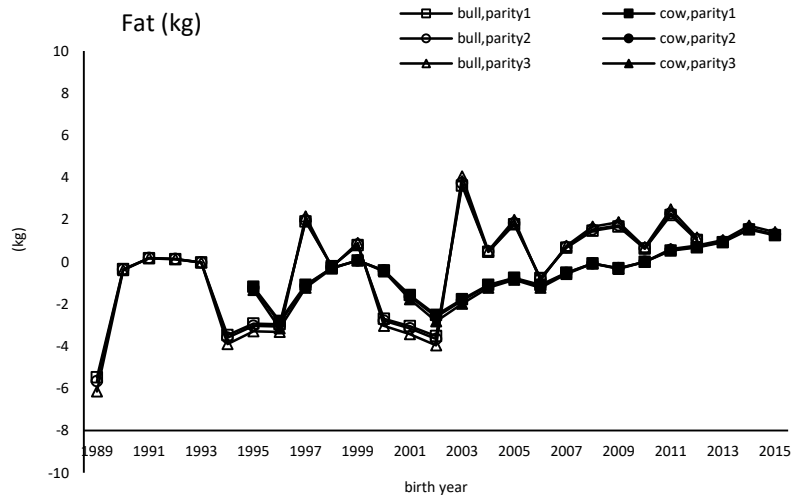


# Genetic trends (lactation basis at THI = 80 continuously) 1



- *Difficult to find trends, both of the previous (left) and the present (right) study*
- *Genetic base = cows born in 2010*

# Genetic trends (lactation basis at THI = 80 continuously) 2



- *Trend changed, though common HT effects for all lactations in the previous study (left).*
- *Difficult to find trend in the present study (right)*

# Conclusions

- Given the fact that animals have never been selected for HT directly in Japan, the genetic trends in the present study were expected.
- More studies are required to further improve % of positive animals.
- The pre-adjustment provides better estimates than those derived from the previous study.

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