Genetic parameter estimation of heat tolerance in the US Holstein and Jersey breeds

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College of Agricultural & Environmental Sciences

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How dairy cattle experience heat

To maintain a constant body temperature, heat gained has to equal heat loss:

$$Heat\ loss = Heat\ Gain$$

$$Heat\ loss = Heat\ Produced + Environmental\ Heat$$

Heat stress occurs when heat gain *exceeds* heat loss:

$$Heat\ loss < \ Heat\ Gain$$

$$Heat\ loss < Heat\ Produced + Environmental\ Heat$$

Robertshaw (1985); Hansen (1994)

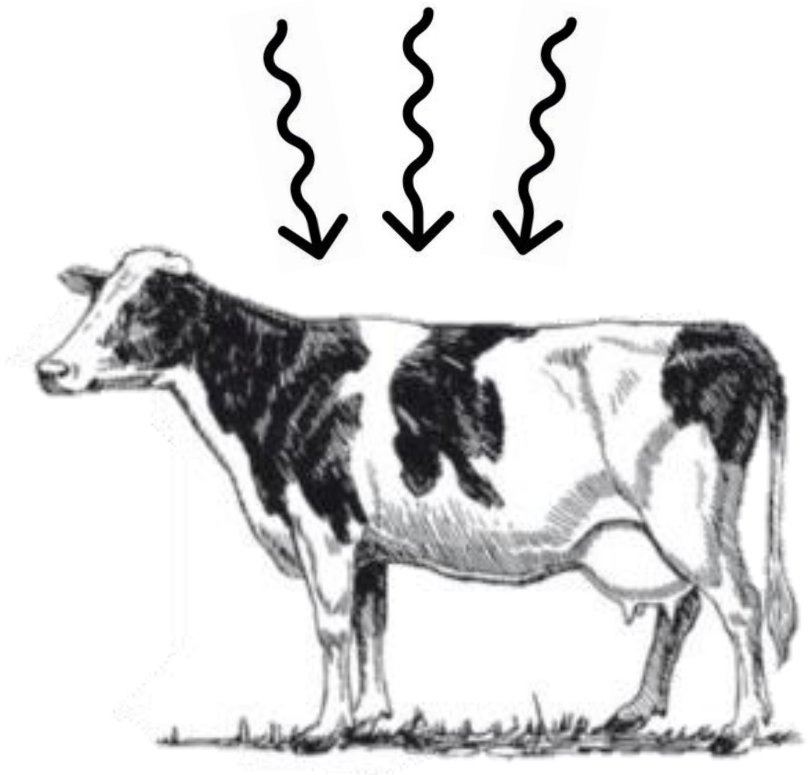
Excessive environmental heat

↑ water consumption

↓ feed intake (DMI)

↑ somatic cell count

↓ milk yield



↓ fertility

↓ rumen function

↓ immunity

↑ risk of mastitis/disease

Heat management strategies

Environmental:

Sprinklers

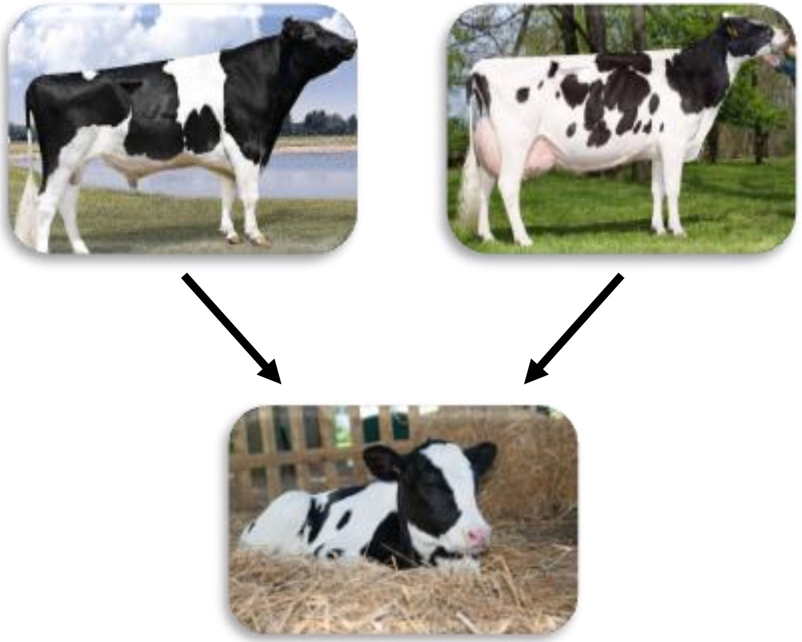
Shade

Ventilation/fans

Feed/water schedule

Genetic Selection:

breeding for heat tolerance



Goal of this research

To estimate genetic parameters for production traits in US Holstein and Jersey cattle under heat stress

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Traits of interest: test-day yields

milk, fat, and protein yield (kg)

SELECT SIRES provided 25.3 million test-day records from 1.6 million cows

Represent 347 herds in 27 US states

→ Data edits for quality control

- First 5 lactations
- ≥5 test-day rec. per lactation
- DIM between 5 and 305 days
- Outlying phenotypes removed (MAD)

→ 12.8 million Holstein test-day records from 923,311 cows

2.1 million Jersey test-day records from 153,714 cows

Represent 331 herds in 27 US states

2015 - 2021

Temperature-humidity index (THI)

$$THI = (1.8 * T_{celsius} + 32) - [(0.55 - 0.0055 * RH) * (1.8 * T_{celsius} - 26.8)]$$

National Research Council (1971)

- Indicator of heat stress risk

  - Little to no heat stress (cyan)
  - Moderate heat stress (green)
  - High heat stress (yellow)
  - Deadly heat stress (red)

Temperature Humidity Index (THI)
Relative Humidity %

C	20	30	40	50	60	70	80	90	100
22	66	66	67	68	69	69	70	71	72
24	68	69	70	70	71	72	73	74	75
26	70	71	72	73	74	75	77	78	79
28	72	73	74	76	77	78	80	81	82
30	74	75	77	78	80	81	83	84	86
32	76	77	79	81	83	84	86	88	90
34	78	80	82	84	85	87	89	91	93
36	80	82	84	86	88	90	93	95	97
38	82	84	86	89	91	93	96	98	100
40	84	86	89	91	94	96	99	101	104

- Weather data obtained from airports closest to each herd
  - Iowa State University's Iowa Environmental Mesonet (IEM)
- 5-day average THI was calculated for each herd-test-day

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Multi-trait Random Regression Model with GxE

$$y = \underline{HTD + (DIM * season) + lact + state + age} + \underline{a + \alpha[f(THI)] + pe + \pi[f(THI)] + e}$$

- y phenotype (milk, fat, and protein yield; kg)

FIXED EFFECTS

- HTD herd-test-day
- DIM days-in-milk
- $season$ calving season
- $lact$ lactation
- $state$ location in US
- age age at calving

RANDOM EFFECTS

- a additive genetic component ← General genetic merit of production
- $\alpha[f(THI)]$ additive heat tolerance genetic component ← Heat tolerance genetic merit of production
- pe permanent environment component
- $\pi[f(THI)]$ permanent environment heat tolerance component
- e residual

Genotype-by-environment interaction (GxE)

- Test-day yields (milk, fat, and protein; kg) were evaluated over an environmental condition defined as a function of THI

$$f(THI) = \begin{cases} 0 & \mathrm{THI_{TD}} \leq \mathrm{THI_{threshold}}\ (no\ heat\ stress) \\ (\mathrm{THI_{TD}} - \mathrm{THI_{threshold}}) & \mathrm{THI_{TD}} > \mathrm{THI_{threshold}}\ (heat\ stress) \end{cases}$$

In Holstein: $\mathrm{THI_{threshold}} = 69$
In Jersey: $\mathrm{THI_{threshold}} = 72$

Variance Component Estimation (VCE)

- Programs (Misztal et al., 2014):
  - GIBBS2F90
    - Implement Bayesian methods with Gibbs sampling
      - 150,000 samples
      - Samples are highly correlated, store every 10th sample
      - Burn-in determined to be 10,000
  - POSTGIBBSF90
    - Program used to analyze samples from GIBBS sampling programs
    - I.e., posterior means, standard deviation, and convergence parameters

Variance Component Estimation (VCE)

- Structure:

$$\text{var}\begin{bmatrix} a \\ \alpha \\ pe \\ \pi \\ e \end{bmatrix} = \begin{bmatrix} \mathbf{A}\sigma^2_a & \mathbf{A}\sigma_{a,\alpha} & 0 & 0 & 0 \\ \mathbf{A}\sigma_{a,\alpha} & \mathbf{A}\sigma^2_\alpha & 0 & 0 & 0 \\ 0 & 0 & \mathbf{I}\sigma^2_{pe} & \mathbf{I}\sigma_{pe,\pi} & 0 \\ 0 & 0 & \mathbf{I}\sigma_{pe,\pi} & \mathbf{I}\sigma^2_\pi & 0 \\ 0 & 0 & 0 & 0 & \mathbf{I}\sigma^2_e \end{bmatrix}$$

$\mathbf{A}$ = pedigree relationship matrix

$\mathbf{I}$ = identity matrix

σ^2_a = var(general additive effect)

σ^2_α = var(HT additive effect)

σ^2_{pe} = var(general pe effect)

σ^2_π = var(HT pe effect)

$\sigma_{a,\alpha}$ = cov(general additive, HT additive)

$\sigma_{pe,\pi}$ = cov(general pe, HT pe)

- Pedigree and all phenotypes were used
- Including genotypes for VCE would have substantially increased computing time

Heritability (h^2) and Correlation

- h^2 for general genetic merit ($no\ heat\ stress$)
- h^2 for genetic merit ($with\ heat\ stress$)
- Genetic correlation between general and heat tolerance additive effects

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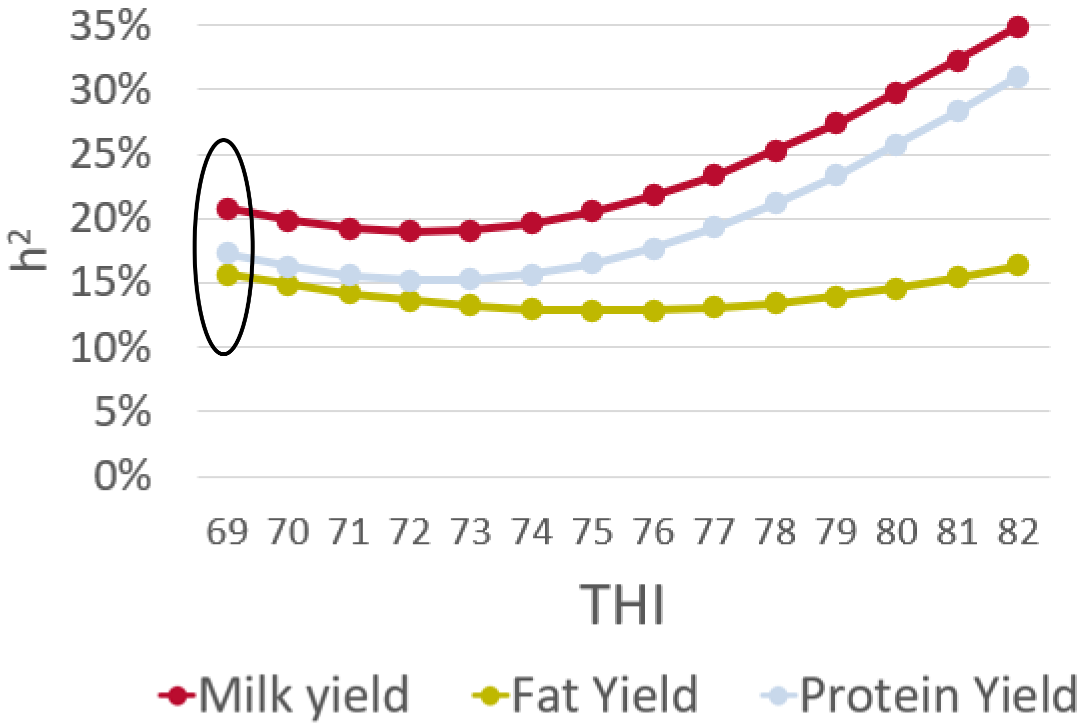
Results: Holstein

Heritability of production traits:

- Milk: 21%
- Fat: 16%
- Protein: 17%

Heritability of production traits across heat stress:

Onset of heat stress for Holstein: 69



Results: Holstein

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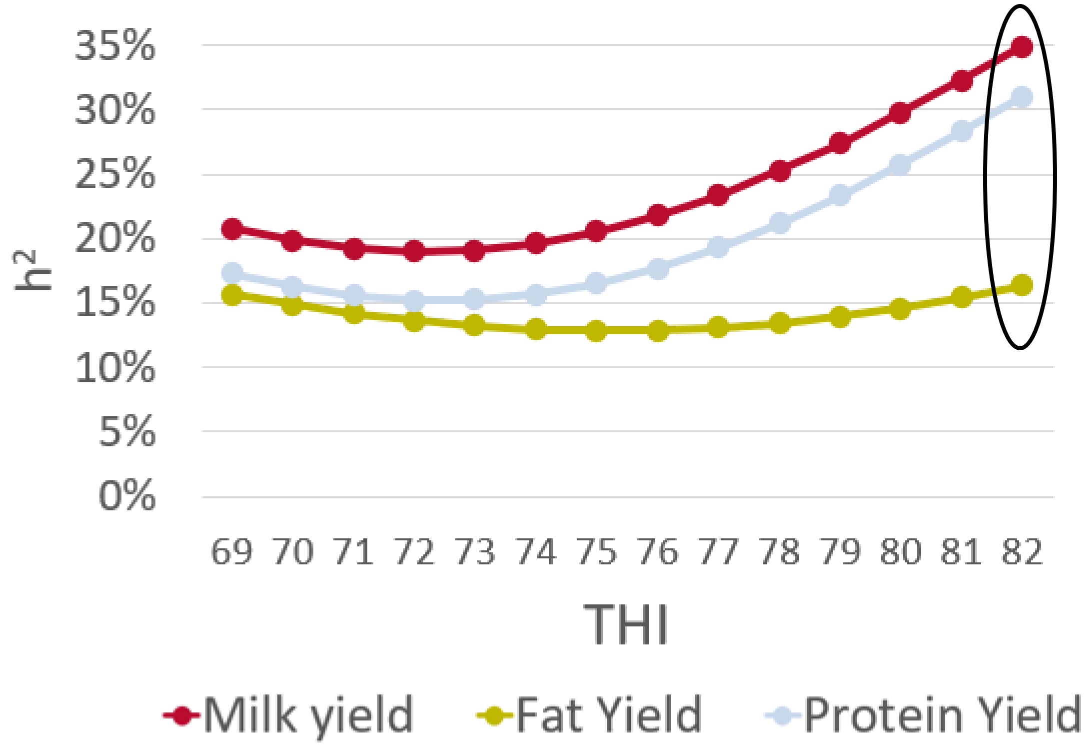

Heritability of production traits under maximum heat stress:

- Milk: 35%
- Fat: 16%
- Protein: 31%

Results: Holstein

Heritability of production traits:

- Milk: 21%
- Fat: 16%
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Heritability of production traits under maximum heat stress:

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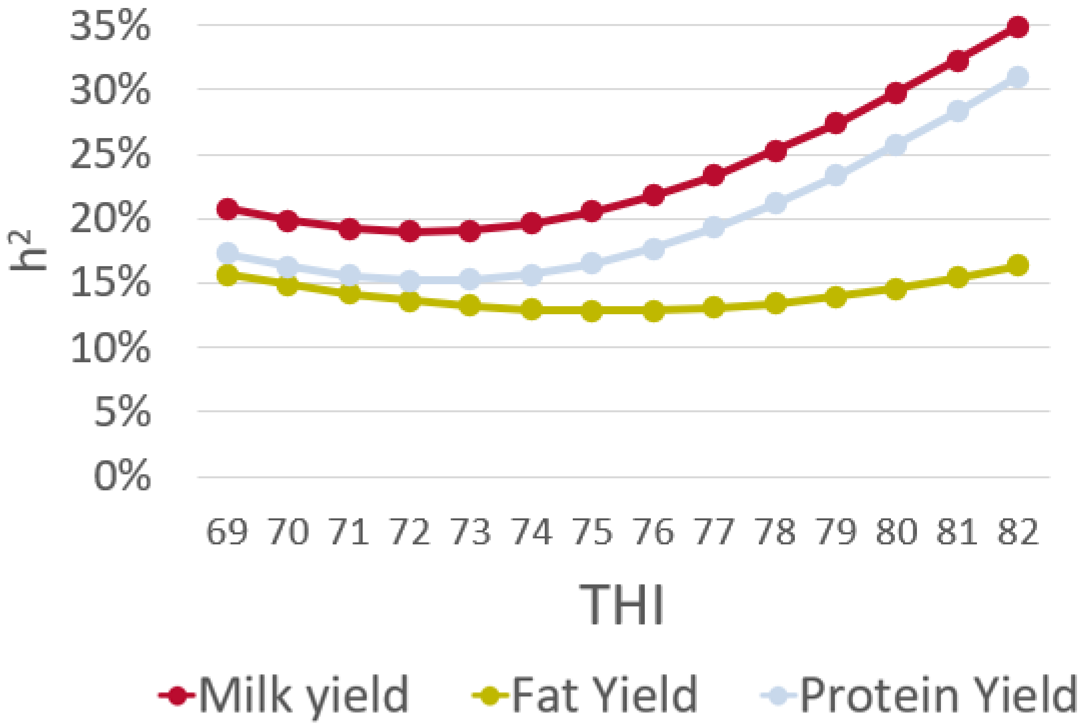
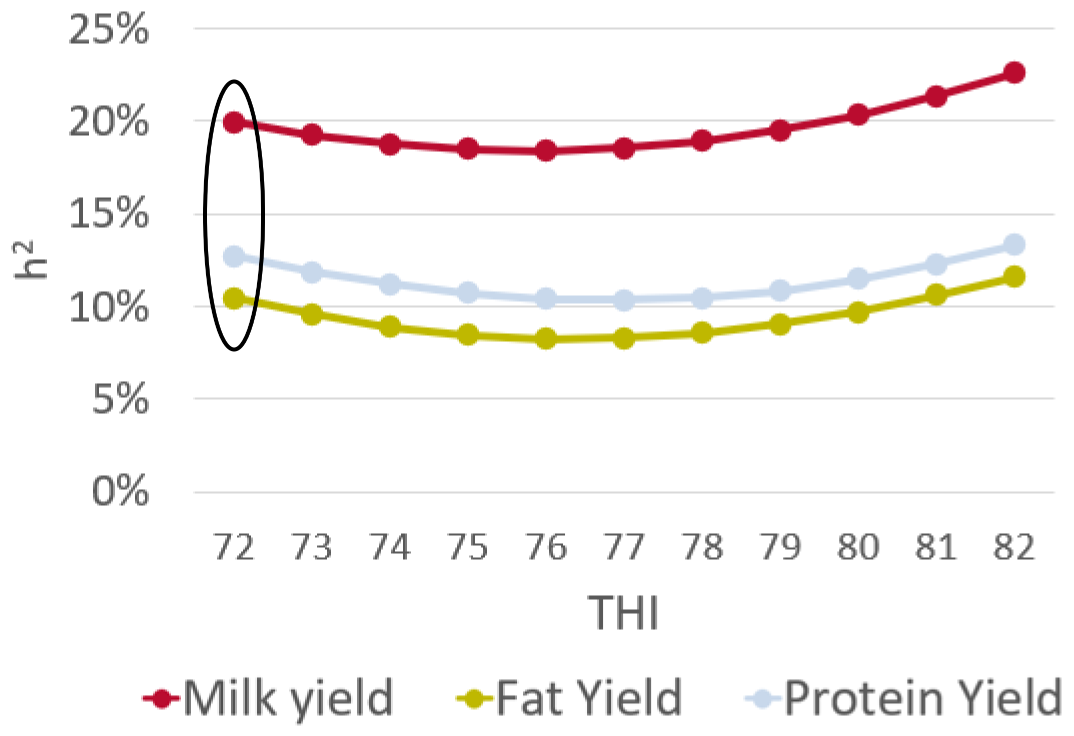


Results: Jersey

Heritability of production traits across heat stress:

Onset of heat stress for Jersey: 72



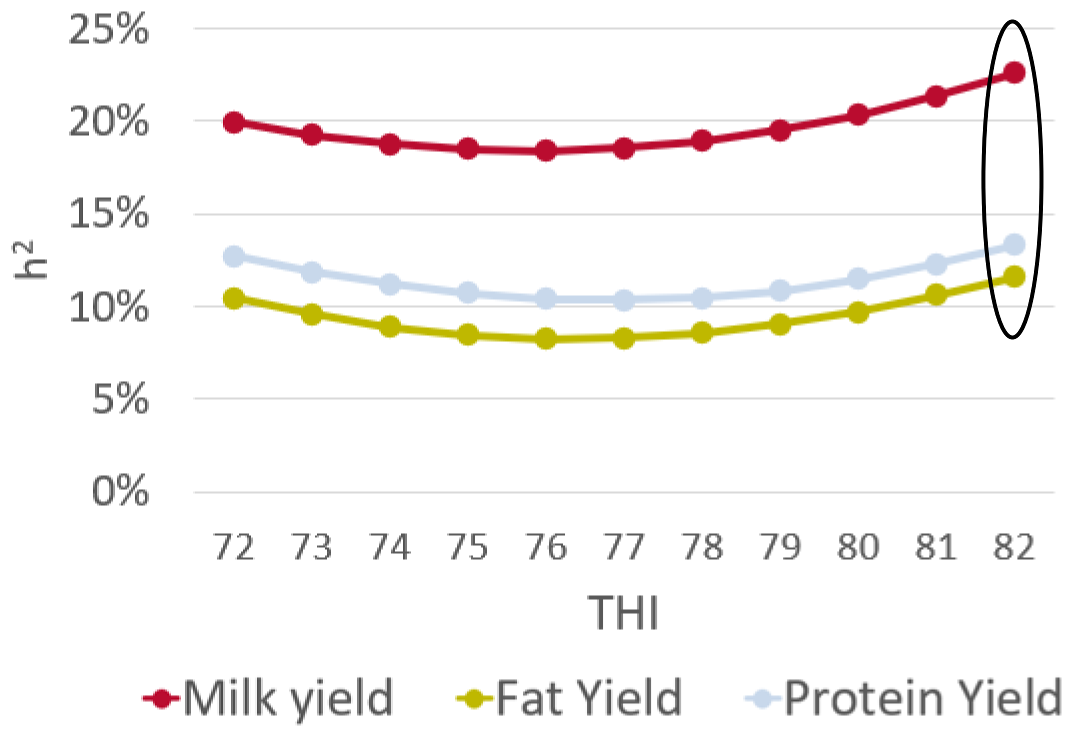
Heritability of production traits:

- Milk: 20%
- Fat: 11%
- Protein: 13%

Results: Jersey

Heritability of production traits across heat stress:

Onset of heat stress for Jersey: 72



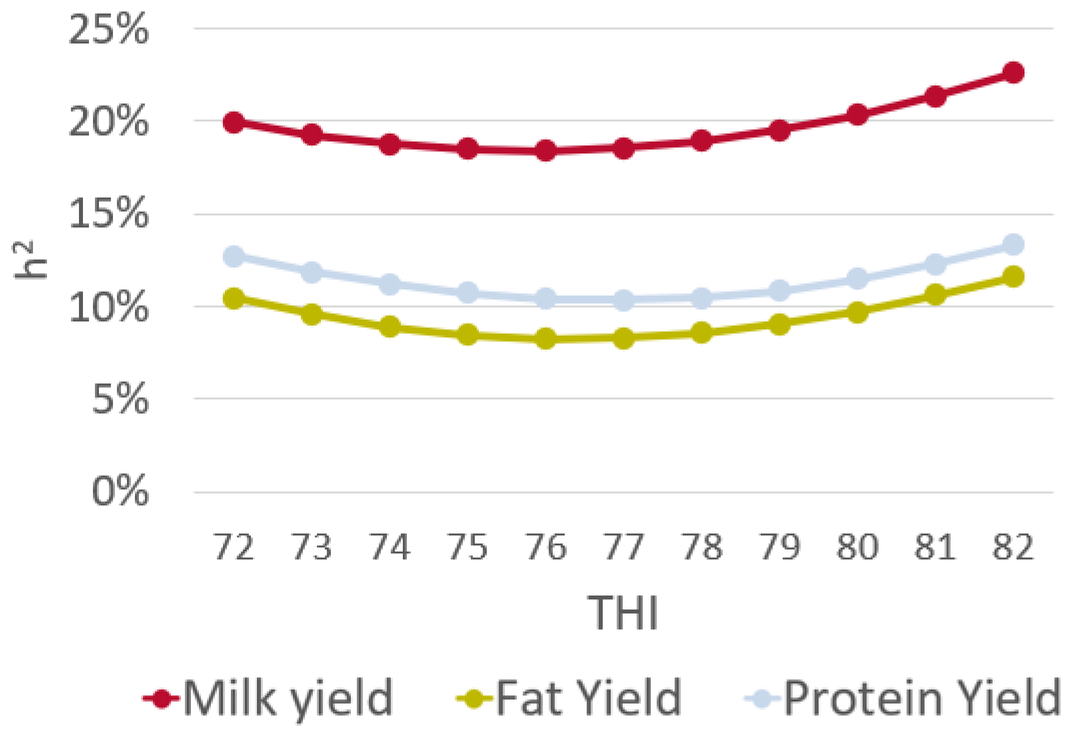
Heritability of production traits under maximum heat stress:

- Milk: 23%
- Fat: 12%
- Protein: 13%

Results: Jersey

Heritability of production traits across heat stress:

Onset of heat stress for Jersey: 72



Heritability of production traits:

- Milk: 20%
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- Milk: 23%
- Fat: 12%
- Protein: 13%

Correlations

Relationship between genetic merit of production and heat tolerance

	Holstein	Jersey
Milk yield	-0.38	-0.37
Fat yield	-0.51	-0.49
Protein yield	-0.43	-0.52

- Negative correlations indicate opposing relationship, but they are moderate
  - Possibility some animals having a *relatively* high genetic merit for production and heat tolerance

Conclusions

- Impact of heat stress on test-day yields depends on both:
  - ~10-30% genetics
  - ~70-90% environment/management

  } breed and trait dependent

- Moderate, negative correlation between genetic merit of production and heat tolerance
  - High producing cows are expected to have a lower heat tolerance

Conclusions continued

- When including the first 5 lactations in the same model:
  - h^2 increases under heat stress for Holstein milk and protein yield
    - Indicating potential to improve heat tolerance through genetic selection
  - The genetic component is not as clear for Jersey production traits

- Currently, lactations are being evaluated separately as first lactation production traits have been observed to be least affected by heat stress

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