Sustainable livestock breeding with a focus on heat stress

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Genetic selection as optimization

• Selection for one trait or an index
• Gains on selected traits
• Losses on correlated antagonistic traits

• Losses in artificial selection
  – Fighting ability (predators and other males), ability to outrun, mating behaviors,…
  – Losses less important because of improved environment/management

• Very poor fitness of domesticated animals when released back into the wild (Frankham, 2008).
Example – Intensive selection for growth in broiler chicken

- Unlimited appetite / obesity ➔ artificial lightning
- Different maturity rate of males and females ➔ separation of sexes
- Poor survival of males ➔ male supplementation
- Increased susceptibility to diseases ➔ antibiotics
- Low hatchability ➔ alternate heating/cooling of incubators

... 

Selection for main traits, improved management for secondary traits
Resilience/efficiency and management intensity

- Resilience
- Efficiency

- Sheep
- Beef
- Pigs
- Dairy
- Chicken

Management intensity
Fundamental limits of selection

Trends in broiler chicken

Challenges for efficient improvement

• Which traits to improve by genetics?
• Which traits to improve by management?

• Should G x E be considered or ignored in selection?
  – Geographic
  – Production systems (e.g., extensive and intensive)
  – Purebred and commercial

• Change with genomics
  – Faster selection for lower $h^2$ traits
  – Widespread use of untested animals
  – QTLs and pleiotropy
Can we improve heat tolerance – example of a project

• Greater variations of climates
• Hotter

• Losses across during heat stress (St. Pierre, 2003)

• Questions
  – Are animals indirectly selected against heat tolerance
  – Is genetic selection for heat tolerance possible?
    • How to use national data for analyses?
  – Is genetic selection preferable to managemental improvements?
Assumption for heat stress model

Breeding value:  \[ BV = a + f(THI) \times v \]

- \( a \) – regular breeding value
- \( v \) – heat-tolerance breeding value
- \( f(THI) \) – function of temperature humidity index
Effect of THI on daily milk production

slope = -0.46
Effect of THI on Non-return rate at 45 days
Genetics results - 2002

- Heat stress begins at about 72F THI (22C at 100% humidity)

- Genetic variability for heat tolerance present but not big

- Relationship between regular and heat tolerance genetics antagonistic at $\sim -0.4$
Heat stress across USA

- Variation in heat tolerance across USA
- Genetic evaluation for heat stress with national data
  - Do colder regions contribute information about heat stress?
  - Profile of heat tolerant bull
  - Can one identify heat-tolerant sires?
  - What are they?

Bohmanova et al. (2005 and 2006)
## Differences between most 100 and least 100 heat tolerant sires

<table>
<thead>
<tr>
<th>Trait</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>-1100kg</td>
</tr>
<tr>
<td>Fat%</td>
<td>+0.2%</td>
</tr>
<tr>
<td>Pro%</td>
<td>+0.1%</td>
</tr>
<tr>
<td>Dairy Form</td>
<td>-1.4</td>
</tr>
<tr>
<td>Udder</td>
<td>+0.7</td>
</tr>
<tr>
<td>Longevity</td>
<td>+0.90</td>
</tr>
<tr>
<td>Fertility</td>
<td>+1.6</td>
</tr>
<tr>
<td>Index</td>
<td>+36</td>
</tr>
</tbody>
</table>

- Selection for fluid milk detrimental to heat stress
- Low accuracy of active sires for heat stress
Is data from colder states useful for heat tolerance evaluation?

EBV_heat_south

Correlation 0.8 for well proven bulls

EBV_heat_south

Same threshold for all states – modeling details not too important

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Optimal THI index?

Different optimal THI in GA and AZ

~ 700 citations

doi:10.3168/jds.2006-513

Temperature-Humidity Indices as Indicators of Milk Production Losses due to Heat Stress

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Heat stress in later parities (Aguilar et al., 2009)

- Holstein U.S. test days
- 3-trait RR and RPT models
- Heat stress effect
- Estimation of parameters
- National evaluation
Variances for three-parity test-day repeatability model

<table>
<thead>
<tr>
<th></th>
<th>Milk</th>
<th>Fat (kg*100)</th>
<th>Protein (kg*100)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Regular</td>
<td>5.6</td>
<td>7.5</td>
<td>6.5</td>
</tr>
<tr>
<td>Heat(+5°C)</td>
<td>4.0</td>
<td>7.0</td>
<td>9.0</td>
</tr>
<tr>
<td>Corr</td>
<td>-0.46</td>
<td>-0.38</td>
<td>-0.47</td>
</tr>
</tbody>
</table>

Genetic variance for heat stress increases up to 5 times in third parity

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Genetic trends of daily milk yield for 3 parities – regular effect

First

Second

Third

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Genetic trends for heat stress effect at 5.5°C over the threshold

- Improvement higher than deterioration
- Test days capture fraction of heat stress information (Freitas et al., 2005)
Holstein mortality in SouthEast

Tokuhisa et al. (2011)

SE Mortality (1-3rd parities) 1999-2008

Mortality

Month

1 2 3 4 5 6 7 8 9 10 11 12
Profile of a “heat-tolerant cow”

- What is a heat tolerant cow?
  - Milk as long as possible?
- Reduces production when dangerous?
- Reduces production early to maintain reproduction
- Thresholds management specific
  - Match genotype to environment

Partially based on Dikmen et al. (2012)
Why no implementation?

• No heat stress in USDA study by Wright et al. (2015)

• Poor milk and fertility ➔ better sprinklers and fans

• Still poor fertility and poor heat detection ➔ timed AI

• Low survival and not enough replacements ➔ sexed semen
New developments

• Heat stress moving north
  – In Canada, threshold of heat stress 57 for protein (Campos et al., 2022)

• With genomics, high reliability even for cows

• Genetic evaluation for heat stress in Australia

• New interest by AI companies, e.g., Select Sires (Taylor et al., 2022), and possibly CDCB
Theoretical and realized heat loads in pigs

Year-Month of slaughter

Carcass weight (kg)

Heat Load*0.15+24

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Zumbach et al., 2007
Heat stress in purebred and crossbred pigs

Fragomeni et al., 2016)

Better environment almost eliminates heat stress
WW Direct Genetic Trend for Angus in Southeast

Genetic SD units

Birth year

No heat stress
High heat stress

(Bradford et al., 2016)

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Studies on Genetics of Heat Tolerance in Dairy Cattle with Reduced Weather Information via Cluster Analysis

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Comparison of lactational responses of dairy cows in Georgia and Israel to heat load and photoperiod

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Utility of on- and off-farm weather records for studies in genetics of heat tolerance

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Short communication: Genetic effects of heat stress on days open for Thai Holstein crosses

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Genetic components of heat stress in finishing pigs: Parameter estimation

B. Zumbach, I. Misztal, S. Tsuruta, J. P. Sanchez, M. Azain, W. Herrig, J. Holl, T. Long, and M. Culperton

J. Dairy Sci. 92:4689–4696

Short communication: Trends for monthly changes in days open in Holsteins

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Multiple trait genomic evaluation of conception rate in Holsteins

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Relative association between somatic cell score and mastitis resistance traits in dairy cattle

J. Dairy Sci. 94:1592–1596
doi:10.3168/jds.2010-3491

Multiple trait genomic analysis of Mastitis Resistance in Holsteins

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Validation of single-step genomic predictions using the linear regression method for milk yield and heat tolerance in a Thai-Holstein population

Piriaporn Singkhapreecah, Ignacy Misztal, Jorge Hidalgo, Daniela Lourenco, Sayon Buaban, Chanskit Chankitiskul, and Wuttigrai Boonkum

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Lessons from heat stress studies

• Traits change over time
  – Indirect selection
  – Changing management

In genomics, use of more than 2 generations not useful (Cesarani et al., 2020)

• Know your data, e.g., little heat stress in first parity
• Managements modifications for heat stress successful
• Genomics opens new frontier
Hypothetical trend changes with genomics

Production (high $h^2$)

Raw fitness (low $h^2$)

Management

Realized fitness

Genomic selection
Changes in (co)variances in pigs due to genomic selection

Heritability for growth

Genetic correlation with reproduction

Heritability decreases, antagonistic correlations intensify

Is intensive selection for RFI detrimental?
Feed conversion from one company

Improvement in feed conversion of broilers (C500 at 42 days of age) – Decrease in 2 to 2.5 points per year

2.24 to 1.58 from 1987 to 2020
Feed conversion from one company

Assuming linear trend, 1 in 29 years, 0.5 in 54 years
Conclusions

• Selection as optimization –赢家和输家特征
  – 尝试识别败者特征

• 少效率物种更稳定

• 基因与管理之间的作用

• 通过基因组学，有录制特征的机会和未录制特征的危险

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