Novel phenotypes to improve the rate of genetic gain in fertility for dairy cattle in New Zealand

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Research Objective

Genetic gain in fertility is accelerated through increased accuracy and reliability of sires using novel, earlier-in-life predictors of cow fertility.
Talk Overview

• Fertility Research Herd (pilot)
• Traits of Interest
• Large Scale Validation Study
  – Animal Selection
  – Phenotyping Protocols
  – Future Work
Fertility Research Herd

• ~500 Holstein-Friesian cows: half low and half high Fertility BV
• Translated to extreme divergence in reproductive phenotypes
• Provides a model to observe novel phenotypes that could be predictive of fertility
Traits of Interest

- Onset of Puberty
- Anogenital Distance (AGD)
Onset of Puberty

Meier et al., unpublished

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### Onset of Puberty

Heritability of 30% (Dennis et al, 2018)

<table>
<thead>
<tr>
<th>Trait</th>
<th>High FBV (n=275)</th>
<th>Low FBV (n=249)</th>
<th>SD</th>
<th>P val.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at puberty (d)</td>
<td>358</td>
<td>379</td>
<td>6</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>LWT at puberty (kg)</td>
<td>271</td>
<td>296</td>
<td>4</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Percentage mature LWT</td>
<td>51</td>
<td>55</td>
<td>1</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

21 DAYS SOONER  25 KGs LIGHTER
Anogenital distance (AGD)

AGD is normally distributed, highly variable & moderately heritable

Canadian HF – association with cow fertility

Irish HF – no association with cow fertility
Validation Study

Improve statistical power to validate and extend key findings of the pilot study
Validation Study

• Variances/Heritability's
  – Age of puberty (P4 measures, Pedometers)
  – AGD

• Covariances
  – Lactation (August 2020 to June 2021)
  – Fertility (October 2020)

• GWAS
  – Age of puberty
  – AGD
Enrollment Criteria

- Excellent data recording
- Variety of sires represented
- Majority Friesian
Herd Fertility Breeding Value

Herd Breeding Worth

Herd Fertility Breeding Value

Herd Breeding Worth

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5000 heifers enrolled
59 sires with at least 5 daughters in at least 3 herds
Phenotyping - Puberty

• Three blood samples for plasma progesterone (P4) – monthly intervals
  – Weekly is optimal but not practical
  – Expect lower heritability of ~18%*
  – Sufficient to meet our research objective*

• First samples timed for when 50% of the animals have reached puberty

*Amer & Dennis, AbacusBio
Phenotyping - Puberty

Subset of 2000 heifers to wear pedometers for three months

– Potential for wider phenotyping in the future
– Higher resolution than P4
Phenotyping – Other

• Weight / Height (once)
• Anogenital Distance (once)
• Lactation (August 2020 to June 2021)
• Fertility (October 2020)
Genotyping

Genotyped Weatherby's Versa chip (50k, Illumina)

- Sire verification
- Increased accuracy of breed proportions
- GWAS
Future

- Idea 1
- Idea 2

Large Scale Phenotypic Data

- Test Proof of Concept
  Robust Genetic Parameter Estimation

- National Genetic Evaluation

Pilot

Validation

Implementation/Routine
Acknowledgements

Funding

• Ministry of Business, Innovation and Employment (MBIE)
• Farmer Levy (DairyNZ Inc.)

DairyNZ technical team involved in planning and data collection.
Thank you
## Observations: Fertility Research herd

### 1\textsuperscript{st} lactation - 2017/18 (raw means)

<table>
<thead>
<tr>
<th>Parameter (%)</th>
<th>High Fertility BV</th>
<th>Low Fertility BV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numbers</td>
<td>257</td>
<td>224</td>
</tr>
<tr>
<td>3-week submission rate</td>
<td>87</td>
<td>48</td>
</tr>
<tr>
<td><strong>6-week in-calf rate</strong></td>
<td><strong>67</strong></td>
<td><strong>33</strong></td>
</tr>
<tr>
<td>Not-in-calf rate (12 weeks mating)</td>
<td>18</td>
<td>42</td>
</tr>
</tbody>
</table>

### 2\textsuperscript{nd} lactation - 2018/19 (raw means)

<table>
<thead>
<tr>
<th>Parameter (%)</th>
<th>High Fertility BV</th>
<th>Low Fertility BV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numbers</td>
<td>204</td>
<td>121</td>
</tr>
<tr>
<td>3-week submission rate</td>
<td>87</td>
<td>55</td>
</tr>
<tr>
<td><strong>6-week in-calf rate</strong></td>
<td><strong>74</strong></td>
<td><strong>39</strong></td>
</tr>
<tr>
<td>Not-in-calf rate (11 weeks mating)</td>
<td>13</td>
<td>44</td>
</tr>
</tbody>
</table>
## AGD vs. cow fertility

<table>
<thead>
<tr>
<th>Fertility traits</th>
<th>‘Short’ &lt;105 mm</th>
<th>‘Long’ ≥105 mm</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number (n)</td>
<td>360</td>
<td>112</td>
<td></td>
</tr>
<tr>
<td>3-wk submission rate</td>
<td>74 ± 4</td>
<td>47 ± 6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>6-wk submission rate</td>
<td>83 ± 4</td>
<td>56 ± 6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>6-wk in-calf rate</td>
<td>57 ± 4</td>
<td>29 ± 5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Final in-calf rate</td>
<td>77 ± 3</td>
<td>53 ± 5</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

In this population, AGD is variable, normally distributed, moderately heritable and associated with cow fertility.
Estimating the genetic correlation

SFM estimates based on 80 sires
Amer & Dennis, AbacusBio
Number of sires is key to accurate $rg$

SFM estimates based on 4000 heifers
Amer & Dennis, AbacusBio
Fertility information from a bull’s daughters

- **Aug Year 0**: Bull is born
  - Parent average only

- **Oct Year 1**: Bull is mated
  - Parent average only

- **Aug Year 2**: Daughters born
  - Parent average only

- **Oct Year 3**: Puberty measures
  - Parent average only

- **Nov Year 4**: Daughter calving
  - Parent average + 50 puberty records + 60 PM21 records

- **Nov Year 5**: PM21
  - Parent average + 50 puberty records + 60 PM21 records

- **Nov Year 6**: CRA2 recorded
  - Parent average + 50 puberty records + 60 CR42 records

- **Year 7 +**: Widespread CRA2
  - Parent average + 50 puberty records + 500 PM21 records + 500 CR42 records
What we learnt from SFM

<table>
<thead>
<tr>
<th>Phenotype</th>
<th>Heritability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perfect age at puberty</td>
<td>0.36</td>
</tr>
<tr>
<td>Activity meter with minor errors</td>
<td>0.33</td>
</tr>
<tr>
<td>Single progesterone</td>
<td>0.07 to 0.1</td>
</tr>
<tr>
<td>Two progesterone (4 wks apart)</td>
<td>0.15</td>
</tr>
<tr>
<td>Three progesterone (4 wks apart)</td>
<td>0.18</td>
</tr>
</tbody>
</table>

*Modelling accounts for progesterone detected between days 6 and 17 of 21 d cycle
Amer & Dennis, AbacusBio
When do we start sampling?

<table>
<thead>
<tr>
<th>Average heifer age (d)</th>
<th>Week 1 (% attained puberty)</th>
<th>Week 5 (% attained puberty)</th>
<th>Week 9 (% attained puberty)</th>
<th>Heritability *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Too early</td>
<td>244 (2%)</td>
<td>272 (9%)</td>
<td>300 (23%)</td>
<td>0.135</td>
</tr>
<tr>
<td>Early</td>
<td>272 (9%)</td>
<td>300 (24%)</td>
<td>328 (43%)</td>
<td>0.180</td>
</tr>
<tr>
<td>Little early</td>
<td>300 (23%)</td>
<td>328 (43%)</td>
<td>356 (63%)</td>
<td>0.195</td>
</tr>
<tr>
<td>Little late</td>
<td>328 (43%)</td>
<td>356 (63%)</td>
<td>386 (79%)</td>
<td>0.180</td>
</tr>
<tr>
<td>Late</td>
<td>356 (65%)</td>
<td>386 (80%)</td>
<td>414 (90%)</td>
<td>0.128</td>
</tr>
<tr>
<td>Very late</td>
<td>386 (79%)</td>
<td>414 (88%)</td>
<td>442 (93%)</td>
<td>0.080</td>
</tr>
</tbody>
</table>

*Modelling accounts for progesterone detected between days 6 and 17 of 21 d cycle

Amer & Dennis, AbacusBio