ABSTRACT: A total of 9,675 reproductive ultrasound records from 8,174 dairy cows were used to estimate the association between production and performance traits with detailed reproductive phenotypes. Cows with greater phenotypic milk yield had a greater likelihood of multiple ovulations and cystic ovaries, whereas greater fat and total solid yield had a reduced likelihood of cyclicity. Greater genetic potential for milk and protein yield was associated with a greater odds of multiple ovulations. Increased genetic potential for milk reduced the likelihood of cyclicity. Genetic potential for highest SCS had a lower likelihood of multiple ovulations, but increased the odds of anestrous and poor uterine health. Cows with genetic merit for superior reproductive performance and survival were less likely to have multiple ovulations, cystic ovaries and poor uterine health and were more likely to be cyclic, relative to cows with inferior genetic merit.

Key words: reproduction; phenotypic; genotypic.

Introduction

Dairy cow breeding goals in the early twenty-first century were broadened to include functional traits including reproductive performance (Miglior et al., 2005). Many of these breeding goals include aggregate reproductive phenotypes such as calving interval (Berry et al., 2014). Such reproductive phenotypes are an accumulation of several underlying, more detailed, reproductive characteristics such as the ability of the animal to return to oestrus post-calving, concurrent with prompt uterine involution ensuring suitability for the establishment of pregnancy, the ability to express oestrus, as well as the ability to conceive and maintain pregnancy (Berry et al., 2014). Although the existence of antagonistic associations between selection for milk production and traditional reproductive traits is already well established (Berry et al., 2014) there is limited knowledge on the association between phenotypic milk production as well as genetic merit for production and performance traits with detailed reproductive traits such as follicular dynamics and uterine environment.

The objective of the present study therefore was to estimate the phenotypic and genetic association between production and performance traits with detailed reproductive phenotypes recorded using ultrasonography including multiple ovulations, cystic ovaries, cyclicity, and uterine environment.

MATERIALS AND METHODS

Ultrasound scans of the reproductive tract and individual cow milk test day records (March 2008 to October 2012) were available from the Irish Cattle Breeding Federation (ICBF) database. Only ultrasound scans from non-pregnant cows calved between 10 and 70 days were retained. Smoothing splines with 6 knot points were fitted separately to individual cow test-day milk, fat and protein yield and predicted milk, fat, protein and total solid yields for the day of the scan were calculated. Yields were standardized within each of the parity groups (i.e. 1, 2, 3, 4 and 5+) and categorized as > 0.5 standard deviation (SD) below the mean (low), ± 0.5 SD from the mean (medium) and >0.5 SD above the mean (high).

Detailed reproductive phenotypes were generated from ultrasound examinations on the day of the scan and are described in detail by Fitzgerald et al. (2014) and Carthy et al. (2014). Phenotypes generated included multiple ovulations, cystic ovaries, cyclicity, and uterine score on the day of the scan. Multiple ovulations were defined by the presence of ≥2 corpora on the ovary. Cystic ovaries were defined by the presence of a fluid-filled structure (>30 mm in diameter) on the ovary at the time of ultrasonography. Cystic ovaries encompassed both follicular and luteal cysts. Cyclicity was defined by the identification of a corpus luteum on the ovary at the time of ultrasonography. Multiple ovulations, cystic ovaries and cyclicity were coded as binary traits for analysis. Uterine health score was assessed on the level of luminal fluid and tone in the uterine horns. Four uterine health score classes were derived: 1) poor uterine tone, inflammation with >60mm of luminal fluids; 2) poor uterine tone with 5-60mm of luminal fluids; 3) normal uterine tone with 2.5mm of luminal fluids and 4) normal uterine tone with <2mm luminal fluids. Contemporary group of herd-year-season of calving was defined as described in detail by Berry and Evans (2014). Only contemporary groups with at least 5 records were retained. Following editing, 9,675 ultrasound records on 8,174 lactating cows from 307 commercial herds remained.

PTAs for milk production, SCS, calving interval and survival. Individual cow predicted transmitting ability (PTA) for milk yield, fat yield, and protein yield were available from the ICBF. Individual cow PTA for somatic cell score (SCS), calving interval, and survival were also available from the ICBF. Cows were categorized into 3 groups of equal size (i.e., low, medium, and high) based on PTAs for milk yield, fat yield, protein yield, as well as SCS, calving interval, and survival.

Statistical analyses. Factors associated with the logit of the probability of the existence of multiple ovulations, cystic ovaries, or cow cyclicity at the time of ultrasonography were quantified using generalised
yield, a similar trend of an increased risk of multiple
following adjustment for difference in genetic merit for
relative to the lowest yielding category of cows.
and total solid yield had 0.89 to 0.93 the odds of cyclicity
therefore influence the likelihood of detailed reproductive
in the high production cows persisted, although not
ovulations and cystic ovaries and a lower risk of cyclicity
metabolism which can impair normal folliculogenesis in
manifestation of multiple ovulations, cystic ovaries and
anestrus is most likely due to alterations in hormonal
selection for higher milk production and reproductive
results confirm a substantial association between genetic
production were less likely to be cyclic on the day of the
production were less likely to be cyclic on the day of the
In general, cows with greatest genetic merit for milk
nevertheless associated with the likelihood of multiple
0.69) compared to cows with inferior genetics for these
0.45 – 0.79 (i.e., progression to subsequent lactation) were less likely
temporary infertility related to cystic ovaries and the potential negative effect of multiple
traits (Table 2). Temporary infertility related to cystic
in the elite genetic merit group for milk and protein were
between 2.75 and 3.24 times more likely to
nutrition and reproduction. Multiple ovulations,
cows categorized into the medium fat:protein ratio group
selection for higher milk production and reproductive
conditions in Irish dairy cows. Neither cystic ovaries nor
uterine score (US) for different levels of genetic merit for milk yield, fat yield, protein yield and somatic cell score (SCS)
Table 1: Odds ratio (95% confidence interval) for multiple ovulations (MO), cystic ovaries (CYST), cyclicity (CYC) and uterine score (US) for different levels of genetic merit for milk yield, fat yield, protein yield and somatic cell score (SCS)

<table>
<thead>
<tr>
<th>Trait</th>
<th>Milk (kg)</th>
<th>Fat (kg)</th>
<th>Protein (kg)</th>
<th>SCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MO&lt;sup&gt;§&lt;/sup&gt;</td>
<td>Med 1.42 (1.13 – 1.78)</td>
<td>1.08 (0.87 – 1.34)</td>
<td>1.31 (1.05 – 1.63)</td>
<td>0.79 (0.64 – 1.06)</td>
</tr>
<tr>
<td></td>
<td>High 1.59 (1.27 – 2.00)</td>
<td>1.21 (0.97 – 1.51)</td>
<td>1.39 (1.11 – 1.74)</td>
<td>0.69 (0.55 – 0.87)</td>
</tr>
<tr>
<td>CYST&lt;sup&gt;§&lt;/sup&gt;</td>
<td>Med 1.28 (0.86 – 1.91)</td>
<td>0.90 (0.61 – 1.34)</td>
<td>1.25 (0.84 – 1.85)</td>
<td>0.73 (0.50 – 0.99)</td>
</tr>
<tr>
<td></td>
<td>High 1.51 (1.06 – 2.26)</td>
<td>1.30 (0.89 – 1.88)</td>
<td>1.49 (1.02 – 2.17)</td>
<td>0.62 (0.41 – 0.93)</td>
</tr>
<tr>
<td>CYC&lt;sup&gt;§&lt;/sup&gt;</td>
<td>Med 0.70 (0.56 – 0.87)</td>
<td>0.77 (0.63 – 0.94)</td>
<td>0.76 (0.62 – 0.94)</td>
<td>1.59 (1.30 – 1.94)</td>
</tr>
<tr>
<td></td>
<td>High 0.50 (0.40 – 0.62)</td>
<td>0.79 (0.64 – 0.97)</td>
<td>0.67 (0.54 – 0.82)</td>
<td>2.66 (2.09 – 3.37)</td>
</tr>
<tr>
<td>US&lt;sup&gt;§&lt;/sup&gt;</td>
<td>Med 1.04 (0.93 – 1.76)</td>
<td>1.04 (0.93 – 1.76)</td>
<td>1.08 (0.33 – 3.58)</td>
<td>1.14 (1.00 – 1.29)</td>
</tr>
<tr>
<td></td>
<td>High 0.93 (0.81 – 1.06)</td>
<td>0.93 (0.81 – 1.06)</td>
<td>1.00 (0.87 – 1.14)</td>
<td>1.36 (1.20 – 1.55)</td>
</tr>
</tbody>
</table>

<sup>§</sup>Referent category (i.e. odds ratio = 1) was low.
<sup>¥</sup>Referent category was poor uterine health (i.e. odds ratio = 1).

RESULTS AND DISCUSSION
The overall prevalence of multiple ovulations, cystic ovaries and cyclicity in the dataset was 7.04%, 1.91% and 89.75%, respectively. Prevalence of uterine scores from 1 to 4 was 1.09%, 12.71%, 20.83% and 65.38%. Daily milk yield (mean ± standard deviation) for cows in the high production group was 34.13 ± 6.14 kg; 34.50 ± 5.83 kg and 33.89 ± 6.20 kg, respectively.

Phenotypic Milk Production. Highest milk, fat and protein production cows were 1.53 to 1.81 times more likely to have multiple ovulations compared to the lowest respective yield category, corroborating previous studies that indicated a similar association (Fricke and Wiltbank, 1999; Lopez et al., 2005). Likewise, highest production cows were between 2.75 and 3.24 times more likely to have cystic ovaries on the day of the scan when compared to the lowest production cows. Cows with the greatest fat and total solid yield had 0.89 to 0.93 the odds of cyclicity relative to the lowest yielding category of cows. Following adjustment for difference in genetic merit for yield, a similar trend of an increased risk of multiple ovulations and cystic ovaries and a lower risk of cyclicity in the high production cows persisted, although not always significant. Farm management practices can therefore influence the likelihood of detailed reproductive phenotypes analyzed in this study, independent of the genetic predisposition of the cow for production. The manifestation of multiple ovulations, cystic ovaries and anestrus is most likely due to alterations in hormonal metabolism which can impair normal folliculogenesis in high yielding cows (Wiltbank et al., 2000). Fat:protein ratio was not associated with the likelihood of multiple ovulations (P > 0.05) or cystic ovaries (P > 0.05), but cows categorized into the medium fat:protein ratio group had a lower likelihood of cyclicity compared to the lowest fat:protein ratio group.

Genetic Merit for Milk Production. Cows in the elite genetic merit group for milk and protein were between 1.31 and 1.59 times more likely to have multiple ovulations compared to the cows in the lowest genetic merit production group for the same milk trait (Table 1). In general, cows with greatest genetic merit for milk production were less likely to be cyclic on the day of the scan, with an odds ratio ranging from 0.50 to 0.79 times that of cows with lowest genetic merit for the trait. These results confirm a substantial association between genetic selection for higher milk production and reproductive conditions in Irish dairy cows. Neither cystic ovaries nor uterine score were associated with genetic merit for milk production. Cows with a genetic predisposition for higher SCS had a lower likelihood of multiple ovulations and cystic ovaries but an increased likelihood of cyclicity and compromised uterine health (Table 1).

Reproductive Performance. Multiple ovulations, cystic ovaries, cyclicity, and uterine score on the day of the scan were associated with calving interval and survival. Cows with superior reproductive performance, (i.e., shorter calving interval), and survival (i.e., progression to subsequent lactation) were less likely to have multiple ovulations or cystic ovaries (OR: 0.45 – 0.69) compared to cows with inferior genetics for these traits (Table 2). Temporary infertility related to cystic ovaries and the potential negative effect of multiple ovulations on reproductive performance through its association with twinning, is consistent with the results of the present study indicating that cows selected for genetically superior reproductive performance are less likely to experience cystic ovaries and multiple
ovulations. In addition, cows with superior reproductive performance and survival were more likely to be cyclic on the day of scan (Table 2), potentially reducing the calving interval compared to cows with inferior genetics for reproductive performance. Cows with both superior reproductive performance and survival had 0.76 the odds of compromised uterine score relative to the inferior category for either trait. Impaired uterine environment provides unsuitable conditions for the establishment of pregnancy, thereby negatively affecting reproductive efficiency.

CONCLUSION

The present study confirms a role for production and performance traits on the likelihood of multiple ovulations, cystic ovaries, cyclicity, and uterine environment in this population of Irish dairy cows. Greater phenotypic milk yield was associated with an increase in likelihood of multiple ovulations, cystic ovaries and anestrous. The likelihood of multiple ovulations was significantly higher in cows genetically predisposed to greater milk yields, while the odds of cyclicity on the day of the scan was lower in cows with greater genetic potential for milk yields. Cows with superior reproductive performance had a lower likelihood of multiple ovulations, cystic ovaries, anestrous, and compromised uterine health.

LITERATURE CITED


Table 2: Predicted probability and odds ratio (95% confidence intervals) for multiple ovulations (MO), cystic ovaries (CYST), and cyclicity (CYC) for different levels of genetic merit for calving interval and survival

<table>
<thead>
<tr>
<th>Trait</th>
<th>Calving Interval</th>
<th>Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Predicted probability (%)</td>
<td>Odds ratio</td>
</tr>
<tr>
<td>MO</td>
<td>$P$-value = 0.01</td>
<td>1.75</td>
</tr>
<tr>
<td></td>
<td>Inferior</td>
<td>1.43</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>1.22</td>
</tr>
<tr>
<td>CYST</td>
<td>$P$-value = &lt;0.005</td>
<td>2.56</td>
</tr>
<tr>
<td></td>
<td>Inferior</td>
<td>2.26</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>1.16</td>
</tr>
<tr>
<td>CYC</td>
<td>$P$-value = &lt;0.001</td>
<td>45.68</td>
</tr>
<tr>
<td></td>
<td>Inferior</td>
<td>61.36</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>71.52</td>
</tr>
</tbody>
</table>

*Referent animal was a second parity dairy cow, scanned from January to December from years 2010 to 2012 with average reproductive performance.
*Referent animal was a second parity dairy cow, scanned from January to December from years 2010 to 2012 with average survival.