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Ovarian structures and uterine environment are associated with phenotypic and genetic merit for performance in lactating dairy cows

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ABSTRACT

The objective of this study was to estimate the association between detailed reproductive phenotypes for cows categorized as divergent for phenotypic and genetic performance. The hypothesis was that higher yielding animals, either phenotypically or genetically, would have compromised ovarian and uterine reproductive performance. Detailed reproductive traits including multiple ovulations, cystic ovarian structures, corpus luteum (CL) presence, and uterine environment were available on 9675 ultrasound records from 8174 dairy lactating cows, calved between 10 and 70 days. Cows were categorized, within parity, into low, average, or high for each of the performance traits. There was a greater likelihood of multiple ovulations in cows with greater phenotypic yields (odds ratio: 1.53–1.81) and greater genetic merit for yield (odds ratio: 1.31–1.59) relative to lower performing contemporaries. After adjustment for genetic merit, a similar trend of increased odds (odds ratio: 1.29–1.87) of multiple ovulations in higher yielding cows was observed compared with the lowest yielding category. There was no association between either phenotypic milk composition or genetic merit for milk composition with the likelihood of multiple ovulations. The likelihood of cystic ovarian structures was highest in cows with greatest phenotypic milk yields (odds ratio: 2.75–3.24), greater genetic merit for milk yield (odds ratio: 1.30–1.51), and even after adjustment for genetic merit there was a greater likelihood of cystic ovarian structures in cows with the highest milk yields (odds ratio: 2.71–2.95), compared with cows in the lowest category for each of the milk traits. Cows with average phenotypic milk yields were more likely to have a CL, compared with the lowest yielding category (odds ratio: 1.20–1.23), and these associations remained after adjustment for genetic merit of the trait. The likelihood of CL presence was highest in cows with the lowest genetic merit for milk. Lower fat:protein ratio was associated with an increased likelihood of CL presence compared with cows with greater fat:protein ratio and cows with the highest phenotypic milk composition were more likely to have a CL compared with cows in the lowest composition category. Genetic predisposition to higher somatic cell score was associated with a reduced risk of multiple ovulations (odds ratio: 0.69; 95% CI: 0.55–0.87) but an increased likelihood of CL presence (odds ratio: 2.66; 95% CI: 2.09–3.37) and poorer uterine health score (odds ratio: 1.36; 95% CI: 1.20–1.55). There was a lower likelihood of multiple ovulations, cystic ovarian structures, and poorer uterine health and an increased likelihood of CL presence in cows with superior genetic merit for reproductive performance and survival.

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1. Introduction

Dairy cow breeding goals in the early 21st century were broadened to include functional traits like reproductive performance [1]. Many of these breeding goals include aggregate reproductive phenotypes such as calving interval or days open [2]. Such reproductive phenotypes are an accumulation of several underlying, more detailed, reproductive characteristics such as the ability of the animal to return to estrus post-calving concurrent with prompt uterine involution, the ability to express estrus, as well as the ability to conceive and maintain a pregnancy [2]. Although the existence of antagonistic associations between selection for milk production and traditional reproductive traits is already well established [2], there is limited knowledge on the association between animals divergent for genetic merit for milk production and detailed reproductive traits such as follicular dynamics and uterine environment [3,4]. Moreover, there is a paucity of information on ovarian structures and uterine environment among animals divergent for genetic merit for aggregate reproductive phenotypes such as calving interval or survival.

Therefore, the objective of the present study was to associate both phenotypic and genetic merit for milk production traits with detailed reproductive phenotypes including multiple ovulations, cystic ovarian structures, corpus luteum presence (CL presence), and uterine environment and also to quantify the difference in such detailed reproductive phenotypes among animals differing in genetic merit for calving interval, survival, and somatic cell score. The hypothesis was that higher yielding animals, either phenotypically or genetically, would have compromised ovarian and uterine reproductive performance. Results from the present study will be particularly useful in elucidating the impact of selection for milk production on ovarian structures and uterine environment and also determining if selection for aggregate reproductive phenotypes like calving interval is effective in improving all aspects of detailed reproductive performance.

2. Materials and methods

2.1. Ultrasound scans

Data were available from the Irish Cattle Breeding Federation (ICBF) database on 65,030 transrectal ultrasound observations of the reproductive tract from 41,582 dairy cows in 828 Irish dairy between March 2008 and October 2012. All ultrasonographic measurements were performed by a single company (Reprodoc Ltd., Fermoy, Co. Cork, Ireland; http://www.cowsdna.com). Ultrasonography was performed transrectally using a real-time β-mode ultrasound scanner with a 5-MHz transducer. Size and echogenicity of ovarian follicles, corpora lutea, uterine tone, and uterine luminal fluids were interpreted, and a classification was assigned based on these combined measures. In the present study, only ultrasound examinations from nonpregnant cows calved between 10 and 70 days were retained.

Detailed reproductive phenotypes were generated from the ultrasound examination and are described in detail by Fitzgerald et al. [5] and Carthy et al. [6]. Phenotypes generated included multiple ovulations, cystic ovarian structures, CL presence, and uterine score. Briefly, multiple ovulations were described in cyclic cows by the presence of two or more corpora on the ovary, indicating the ovulation of two or more follicles in the previous cycle. Cystic ovarian structures were described in nonpregnant cows by the presence of a large fluid-filled structure (>25 mm in diameter) on the ovary. A cystic ovarian structure was diagnosed when the CL was <5 mm in diameter or when the CL was absent. CL presence was described by the identification of a CL on the ovary in the presence of follicles not exceeding 25 mm in diameter. A CL could be determined during the metestrous, dioestrous, and proestrous stages of the bovine estrous cycle. Multiple ovulations, cystic ovarian structures, and CL presence were coded as binary traits for analysis. Uterine score was described in nonpregnant cows by an assessment of the level of luminal fluid and tone in the uterine horns [6,7]. Four uterine health scores were derived: (1) poor uterine tone with inflammation and more than 60 mm of luminal fluids; (2) poor uterine tone with 5 to 60 mm of luminal fluids; (3) normal uterine tone with 2 to 5 mm of luminal fluids; and (4) normal uterine tone with less than 2 mm luminal fluids (Fig. 1).

2.2. Cow and herd characteristics

Breed composition of the cows were available from the ICBF database; only cows with ≥75% of breed fraction known were retained and consisted of only dairy herds. The majority of the dairy cows in Ireland were Holstein-Friesian, and 96% of the cows in the present study were Holstein-Friesian. Typically, dairy herds in Ireland are seasonal calving; in the present study, 61% of cows calved between February and May, 9.50% calved between June and September, and 29.50% calved between October and January. The average herd size was 89. Standard practice for dairy cows in Ireland is to house animals during the winter months with animals being turned out to pasture in the spring.

2.3. Phenotypic and genetic milk production

Individual cow test-day records for milk, fat, and protein yield were available from the ICBF database. A smoothing spline with six knot points at 20, 70, 120, 170, 220, and 270 days post-calving was fitted to each cow's individual test-day record using ASReml [8]. Predicted milk, fat, and protein yield on the day of ultrasonography were deduced by interpolation and extrapolation from the fitted splines; total solids yield was calculated as the sum of fat and protein yield. The predicted yield traits were used to determine milk fat and protein concentration as well as the fat-to-protein ratio. Fat-to-protein ratio is often cited as an indicator of energy balance [9], where a high ratio value is proposed to signify a greater negative energy balance in the cow.