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## Monitoring onset of puberty in three genetic strains of Holstein-Friesian dairy cattle

L.R. MCNAUGHTON<sup>1,2</sup>, S.R. MORGAN<sup>1</sup>, P. GORE<sup>1</sup>, G.A. VERKERK<sup>1</sup>, C.W. HOLMES<sup>2</sup> AND T.J. PARKINSON<sup>2</sup>

<sup>1</sup>Dexcel Ltd, Private Bag 3221, Hamilton, New Zealand

### ABSTRACT

Live weight and age at puberty were determined in three strains of Holstein-Friesian dairy cattle in each of two consecutive years. The strains were overseas-origin high-breeding-worth genetics (OS), New Zealand-origin high-breeding-worth genetics (NZH), and New Zealand-origin low-breeding-worth genetics (NZL), similar to the New Zealand dairy cow of the 1970s. Onset of puberty was monitored by weekly measurement of progesterone in a total of 271 heifers. Animals were considered to have attained puberty when plasma progesterone concentrations were greater than 2ng/ml in two out of three consecutive samples. Live weight at puberty differed between the strains (OS > NZH > NZL;  $P < 0.05$ ) but not between years. Age at puberty was affected by strain in Year 1 (OS > NZH > NZL;  $P < 0.01$ ), but not in Year 2. The greater live weight required to attain puberty in OS genotype animals must be recognized in target live weights for rearing of heifers.

**Keywords:** puberty; Holstein-Friesian; age; live weight; nutrition; genotype.

### INTRODUCTION

Female puberty can be defined as the age when mature gametes are produced and reproductive activity (oestrous cycles) is initiated (Foster & Nagatani, 1999). The New Zealand (NZ) system of dairy production is seasonal and requires heifers to conceive at 13 to 15 months of age, depending on their birth date, in order to calve at 22-24 months of age. Early onset of puberty is, therefore, advantageous, to ensure that all heifers are cycling regularly before the start of mating.

Live weight is a key determinant of the onset of puberty (Hafez, 1993), with the live weight at which puberty occurs related to the mature body weight of the particular breed. Manipulation of growth rate results in a change in age, but not live weight at which puberty occurs (Barash *et al.*, 1994; Yelich *et al.*, 1996; Lammers *et al.*, 1999). The Holstein-Friesian (HF) dairy cow of North America and Europe attains a heavier mature live weight than the New Zealand Holstein-Friesian (NZHF) under NZ pasture-based conditions (Harris & Kolver, 2001). Hence, animals of overseas (OS) genetic background are likely to have a greater live weight at puberty, necessitating faster growth rates to reach puberty at the same age as animals of NZ genetic origin (Garcia-Muniz, 1998). The proportion of overseas (OS) HF genetics within the average NZHF cow has increased from 2% in 1978 to 38% in 1998, so that in 1998 only 5% of HF cows in New Zealand had no OS HF genetics (Harris & Winkleman, 2000). This shift in the genetic base will, therefore, have consequences upon the management practices for rearing heifers.

The purpose of this experiment was to monitor the onset of puberty in HF animals of three genotypes, raised under NZ conditions, in order to determine their age and live weight at puberty. It was postulated that OS animals would be older and heavier at puberty than NZ genotype animals, and that there would be no difference in age and live weight at puberty between the two NZ genotypes.

### MATERIALS AND METHODS

#### Animals

Heifer calves of three genetic strains were examined over two consecutive years. The genetic strains were:

- High-Genetic-Merit Overseas Holstein-Friesian (OS),  $n=111$ . OS animals were at least 87.5% OS genetics, with a predicted live weight breeding value (BV) of 84 in the year of birth.
- High-Genetic-Merit New Zealand Holstein-Friesian (NZH),  $n=97$ . NZH animals were at least 87.5% NZHF genetics, with a predicted live weight BV of 48 in the year of birth.
- Low-Genetic-Merit New Zealand Holstein-Friesian (NZL),  $n=63$ . NZL animals were 100% NZ genetics, with a predicted live weight BV of 49 in the year of birth.

Animals were grazed at the Dexcel Grazing Unit (Hamilton, New Zealand). In Year 1, animal numbers necessitated division of animals into four herds, one of each strain and a small, preferentially-fed, group of the lightest animals. The four groups of animals were grazed in adjacent paddocks on pasture of similar quality and at generous feeding levels. In Year 2, all animals were run as one herd of 81 animals. Grass silage and concentrates were fed during the winter of Year 2 after a severe autumn drought.

#### Measurements

Blood samples were taken weekly from each heifer that had reached 195 kg live weight for NZ strains and 215 kg for the OS strain. All prepubertal heifers were sampled for the last four weeks of the sampling period, regardless of their live weight. Sampling ceased 14 days prior to the start of mating to allow induction of oestrus in heifers that were prepubertal. Samples were collected via venipuncture (heparin anticoagulant), placed in ice water and centrifuged within two hours of collection. Plasma was stored at  $-20^{\circ}\text{C}$  until assayed. Progesterone concentrations were measured by radioimmunoassay (Coat-a-Count<sup>TM</sup>, DPC, USA). Intra- and inter-assay

<sup>2</sup>Massey University, Private Bag 11222, Palmerston North, New Zealand

coefficients of variation were 8.6 and 8.2% respectively with an assay sensitivity of 0.06 ng/ml. Puberty was considered to have occurred when plasma progesterone concentrations of 2ng/ml were present in two out of three consecutive samples. The date of puberty was recorded as the time of the first of these samples. Live weights were measured fortnightly using load-cell scales (Trutest, NZ Ltd) and live weight at puberty was estimated by interpolation.

### Statistics

Proportional data were analysed using chi squared (SAS version 8.1). Continuous data were analysed using the mixed procedure of SAS, with a model that included the fixed effect of strain and a random effect of sire, nested within strain.

## RESULTS

Data from the two years of the trial were analysed separately as the differences in feed management between the two years meant that the animals were, effectively, under different nutrition regimens.

### Year 1

Results for the proportion of pubertal animals, birth date, age at puberty, live weight at puberty, average daily live weight gain and predicted mature live weight, by strain for Year 1 are shown in Table 1. Significantly more NZH than OS animals had reached puberty by planned start of mating, even after adjustment was made for the differences in birth date between strains. Significant strain differences were also evident for both age and live weight at puberty. Seven weeks before the end of the sampling period, 35% of all animals had reached puberty, and 76% were pubertal by three weeks before the end of sampling.

**TABLE 1:** Year 1 (1999). Proportion of pubertal animals, average date of birth, age and weight at puberty, average daily live weight (LWT) gain and predicted mature LWT for overseas-high-genetic-merit (OS), New Zealand-high-genetic-merit (NZH) and New Zealand-low-genetic-merit (NZL) heifers.

	OS n = 76	NZH n = 73	NZL n = 41
Pubertal animals (%) <sup>1</sup>	79 <sup>a</sup>	97 <sup>b</sup>	89 <sup>ab</sup>
Mean birth date	10 <sup>th</sup> August	7 <sup>th</sup> August	13 <sup>th</sup> August
Mean (± sem) age at puberty (days)	373 ± 6.0 <sup>a</sup>	356 ± 6.9 <sup>a†</sup>	329 ± 6.7 <sup>b</sup>
Mean (± sem) age at puberty (d)	373 ± 6.0 <sup>a</sup>	356 ± 6.9 <sup>a†</sup>	329 ± 6.7 <sup>b</sup>
Mean (± sem) LWT at puberty (kg)	274 ± 4.4 <sup>a</sup>	253 ± 4.9 <sup>b</sup>	230 ± 4.9 <sup>c</sup>
Mean (± sem) daily LWT gain (kg/day)	0.73 ± 0.01 <sup>a</sup>	0.68 ± 0.01 <sup>b</sup>	0.67 ± 0.01 <sup>b</sup>
Predicted mature LWT (kg)	640	540	540

<sup>abc</sup> Values within rows, with different superscripts, differ significantly (P<0.05)

<sup>†</sup> Difference between NZH and OS approaches significance (P=0.07)

<sup>1</sup>Only animals ≥ 400 days of age at the end of the sampling period were included, to remove effects of birthdate

<sup>2</sup>Average daily gain from October (3 months) to October (15 months).

### Year 2

Results for the proportion of pubertal animals, birth date, age at puberty, weight at puberty, average daily live weight gain and predicted mature live weight, by strain for year 2 are given in Table 2. There was no effect of strain on the percentage of animals that reached puberty by planned start of mating even after adjustment for differences in birth date. Age at puberty was not different between strains, whilst live weight at puberty was significantly (P<0.05) different. By contrast to the situation in Year 1, during Year 2, only 9% of animals had reached puberty by 7 weeks before the end of the sampling period, and 50% were still pre-pubertal with three weeks of sampling remaining.

**TABLE 2:** Year 2 (2000). Proportion of pubertal animals, average date of birth, age and weight at puberty, average daily live weight (LWT) gain and predicted mature LWT for overseas-high-genetic-merit (OS), New Zealand-high-genetic-merit (NZH) and New Zealand-low-genetic-merit (NZL) heifers.

	OS n = 35	NZH n = 24	NZL n = 22
Pubertal animals (%) <sup>1</sup>	68	83	61
Mean birth date	3 <sup>rd</sup> August	27 <sup>th</sup> July	10 <sup>th</sup> August
Mean (± sem)			
age at puberty (d)	374 ± 6.5	380 ± 6.5	381 ± 8.1
Mean (± sem) LWT at puberty (kg)	271 ± 6.0 <sup>a</sup>	258 ± 5.9 <sup>a</sup>	237 ± 7.3 <sup>b</sup>
Mean (± sem) daily LWT gain (kg/day)	0.67 ± 0.01 <sup>a</sup>	0.66 ± 0.01 <sup>a</sup>	0.59 ± 0.01 <sup>b</sup>
Predicted mature LWT (kg)	640	540	540

<sup>abc</sup> Values within rows, with different superscripts, differ significantly (P<0.05)

<sup>1</sup>Only animals ≥ 400 days of age at the end of the sampling period were included, to remove effects of birthdate

<sup>2</sup>Average daily gain from October (3 months) to October (15 months).

## DISCUSSION

These results indicate that genetic strain of Holstein-Friesian influences age at puberty largely through the influence of strain on live weight. Strain had a significant effect on the proportion of animals that reached puberty only in Year 1 when overall growth rates were acceptable and more NZH than OS heifers reached puberty by planned start of mating. Likewise differences in age at puberty between strains were only recorded in Year 1 of the trial. Overseas animals were heavier at puberty than animals of NZ-origin, and NZL animals were lighter at puberty than both NZH and OS heifers. Due to inadequate feeding during Year 2 associated with a drought period, the effect of strain on age at puberty was not seen.

In a related trial in Ireland, more NZ Holstein-Friesians (imported as embryos, with the same sires as NZH in the present trial) reached puberty by the mating start date than Irish high merit Holstein-Friesians (cows that have a significant proportion of North American and European genetics; McGrath *et al.*, 2001). Live weights at puberty recorded in this trial are similar to those recorded in other trials with heifers of similar genetic background (Table 3). The live weight variation between the NZ lines at puberty, as reported in this study, is similar to that between two NZ strains selected for heavy and light mature live weight (Garcia-Muniz, 1998; Table 3). In our study age

at puberty in the NZH and OS animals was greater in Year 1 than in other trials where animals reached puberty at similar live weights (Barash *et al.* 1994; McGrath *et al.* 2001; Table 3). This could be a consequence of lower growth rates in this study than in these reports, which is likely associated with rearing on pasture rather than a concentrate-based diet.

**TABLE 3:** Mean age and live weight (LWT) puberty for various strains of Holstein-Friesian (HF) dairy cattle.

Location and heifer type	Age (days)	LWT (kg)
Israel, OS high genetic merit HF <sup>2</sup>	318	271
Ireland, NZ high genetic merit HF <sup>3</sup>	300	241
NZ, HF selected for heavy mature LWT, 46% OS genetics <sup>4</sup>	345	241
NZ, HF selected for light mature LWT, 12% OS genetics <sup>4</sup>	300	221
NZ, NZHF 1970 low genetic merit <sup>5</sup>	348	218

<sup>1</sup>Present trial; <sup>2</sup>Barash *et al.* (1994); <sup>3</sup>McGrath *et al.* (2001); <sup>4</sup>Garcia-Muniz, (1998);

<sup>5</sup>Pleasant *et al.* (1975)

Age at puberty is responsive to live weight and level of nutrition. The conditions of Year 2 influenced growth rates animals were 20 kg lighter at the end of May in Year 2. Thus, the proportion of animals that were pubertal in each of the strains was lower in Year 2 than in Year 1, yet live weights at puberty were similar to those recorded in Year 1 for animals of similar strains. After the drought period, concentrates (June to September) and silage (June to December) were fed which increased nutrient intakes and live weight. This accelerated growth, which appeared to have assisted puberty onset, may have occurred as a consequence of increased pulsatile secretion of luteinising hormone (Day *et al.*, 1986; Kurz *et al.*, 1990). It may also have caused the loose synchronization of puberty onset, as described by Gonzalez-Padilla *et al.* (1975), to give the more compact pattern of Year 2, with no differences in age at puberty between the strains. The introduction of supplementary feed occurred at a time that allowed the OS animals to reach pubertal live weight at the same age as in Year 1, but would have been too late to allow the NZ strains to reach pubertal live weight at the same age as the previous year. Thus age at puberty was affected by strain in Year 1, but not in Year 2.

These results support the contention that live weight is the more important determinant of the timing of the onset of puberty (Hafez, 1993). OS animals were heavier at puberty than NZ genotype animals, as predicted by the greater live weight BV of OS compared to NZ genetic origin animals. The difference in live weight between the NZ strains was unexpected, given that they had similar predicted live weight BVs. This suggests that either NZL animals reach puberty at a lower proportion of their mature weight than NZH animals, or that the live weight BV for NZL cattle was overestimated. NZL animals in this study were significantly lighter than NZH animals from six months of age, despite similar condition scores. Selection over the past 20-30 years seems to have resulted in heavier NZHF, that need to reach heavier live weights to reach puberty.

Attainment of a proportion of mature live weight has

been proposed as one trigger for puberty onset (Hafez, 1993). Estimates of the proportion of mature weight that NZH, NZL and OS had attained at puberty (47, 43 and 43% respectively), based on predicted mature live weights are similar to those calculated by Garcia-Muniz (1998) for heifers selected for light or heavy mature live weight (both 47%), and differing in proportion of OS genetics (Table 3). Even if OS heifers reach puberty at a lower proportion of mature live weight than NZH animals they still need to attain a heavier absolute live weight, requiring a faster growth rate, and higher feed consumption to reach puberty at the same age as a NZ-origin heifer. Target live weights, therefore, need to be increased for OS-genetic-origin animals. Penno *et al.* (1995) suggested HF heifers should weigh 300 kg at mating based on results with 1992 born HF heifers that would be expected to have an average of 17% OS genetics (Harris & Kolver, 2001). For animals with a high proportion of OS genetics, a target of 340 kg would be more appropriate, whilst 300 kg is a minimum live weight target for NZH animals. Feeding levels in this trial were inadequate for OS animals to reach this target live weight at mating. Setting growth targets that are related to mature live weight, and feeding heifers to ensure targets are met are crucial to ensure animals are cycling before the start of the mating period.

The genetic origin of replacement heifers and their BV for live weight must be considered when setting live weight targets for heifer growth. Setting appropriate targets for the type of animals being farmed, and meeting these are crucial to produce well-grown heifers that are cycling and ready to conceive at the start of the mating period. The present results indicate that target live weights should be highest for the OS and lowest for the NZL strains.

## ACKNOWLEDGEMENTS

The authors wish to thank T.O'Donnell, E. Smith, R Mackenzie, B. Dow, members of the Dexcel Fertility Group and staff of the Dexcel #4 grazing unit for assistance with this project. This study was funded by the New Zealand Dairy Board Global programme. L. McNaughton is the recipient of an AGMARDT Doctoral Scholarship.

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