Effect of Genetic Merit for Milk Production, Dairy Cow Breed and Pre-Calving Feeding on Reproductive Physiology and Performance.

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Contents

1. Summary

The overall objective of this project was to determine, following four experiments, the effects of genetic merit for milk production, dairy cow breed and prepartum feeding on reproductive physiology and performance.

In Experiment 1, groups of high genetic merit Holstein-Friesian, medium genetic merit Holstein-Friesian, and dual-purpose Montbeliarde and Normande cows were studied in each of four years. The dual-purpose cows were selected for milk and beef production. The objective of the study was to determine the effect of dairy cow breed on reproductive performance and associated production parameters. The high genetic merit Holstein-Friesian cows had higher cumulative milk production, lower body condition score (BCS) at calving, larger body condition loss between calving and first service and lower overall pregnancy rate compared with the medium genetic merit Holstein-Friesian, Montbeliarde and Normande cows ($P<0.05$). Cows that did not conceive to first service were retrospectively compared with cows that conceived to first service. Cumulative milk production was higher for cows that did not conceive compared with those that conceived to first service. However, when cows that did not conceive were compared with cows that conceived to first service, within breed, milk production did not differ significantly. Furthermore, milk composition and BCS change between calving and first service did not differ significantly between cows that did not conceive and those that conceived to first service ($P > 0.05$). The results of this study suggest that dairy cow breed has a significant effect on reproductive performance and milk production.

In Experiment 2, Holstein-Friesian cows with high and medium genetic merit for milk production were studied over two years to determine the possible relationships between genetic merit, milk production, body condition, blood metabolic parameters, feed intake and reproductive physiology and performance. The high genetic merit cows had higher milk production, greater body condition loss from calving to first service, lower plasma glucose and insulin-like growth factor-1 and lower first service and overall conception rates than the medium genetic merit cows. Cows that did not conceive to first service

were retrospectively compared to those that conceived to first service within each genetic merit category. Within the high genetic merit category there were no significant differences between the cows that did not conceive and those that conceived to first service in terms of milk production, body condition score change from calving to first service, or plasma concentrations of glucose, non-esterified fatty acids or insulin-like growth-factor-1. However, medium genetic merit cows that did not conceive to first service lost more body condition from calving to first service than did those that conceived to first service. The results of this study suggest that milk production, body condition and blood metabolic parameters are not useful indicators of reproductive performance in high genetic merit dairy cows. Reproductive performance differed between Holstein Friesian cows with differing genetic merit for milk production.

In Experiment 3, the effects of milk production, body condition score and lactation number on the number of oocytes recovered and blastocysts formed were studied following *in vitro* maturation, fertilization and culture of bovine oocytes collected from Holstein-Friesian cows with high and medium genetic merit for milk production. Oocytes from high genetic merit cows formed fewer blastocysts and had lower cleavage and blastocyst formation rates than those from medium genetic merit cows. There was no difference in number of oocytes recovered and subsequent development into blastocysts between the cows in the high milk production group and cows in the low milk production group. Cleavage rate and blastocyst formation rate was greater for oocytes from cows in high BCS than for oocytes from cows in low BCS. Therefore, high genetic merit cows with low BCS yielded oocytes of lower quality. Thus, oocyte quality is likely to contribute to reduced fertility, often evident in high genetic merit dairy cows.

In Experiment 4, the effect of prepartum feeding treatments on reproductive performance in the first 100 days of lactation was studied in Holstein-Friesian cows. Cows fed *ad libitum* grass silage and 3 kg concentrates prepartum had higher body condition score at calving than cows fed 75% grass silage and 25% barley straw. However, the prepartum feeding treatment had no effect on day of first ovulation or embryo quality. Embryo quality was negatively correlated with cumulative milk production and positively correlated with feed intake prepartum. It was concluded that while cows ovulated early postpartum, embryo quality was low.

In the present experiments, the high proportion of Holstein-Friesian genes played a more important role in reducing reproductive performance than milk production. Significant breed differences in reproductive performance were detected.

2. Introduction

The introduction of milk quotas in the European Union in 1984 has led to intensification of dairy farming with increasing milk production per cow, achieved by wide scale usage of Holstein-Friesian (HF) sires. Genetic improvement of North American and European HF cows has mainly focused on increasing milk production. However, selection for milk production alone can lead to deterioration in reproductive performance. Increased milk production has been associated with a lower first service conception rate, a greater number of services per conception and an increased incidence of silent heats and ovarian cysts. It has been reported that the introduction of HF genes was associated with decreased reproductive performance in New Zealand, Dutch and UK dairy herds (Harris et at, 1999, Hoekstra et al.,1994, Royal et al., 1999).

While genetic improvement of the HF dairy cow is mainly focused on increasing milk production, in dual-purpose breeds other traits of economic importance are also considered, e.g. meat production. Energy partitioning may be different in dual-purpose cows compared with HF cows, which may result in less body condition loss in early lactation. However, results from studies that compare production and reproductive performance between HF and dual-purpose cows are inconsistent (Oldenbroek, 1984; Haiger and Solkner, 1995).

The effect of high milk production on the incidence of reproductive disorders may be related to the extent of negative energy balance early postpartum. During early lactation, many high producing cows are unable to consume enough feed to meet their energy demands, resulting in a period of negative energy balance. Early postpartum negative energy balance may delay the interval from calving to first ovulation, which has detrimental effects on later reproductive performance. Changes in body condition score (BCS) during early lactation follow changes in energy balance. This makes the use of BCS an accurate and repeatable method to estimate body energy or fat reserves of dairy cows. Severe body condition losses postpartum has been associated with lower first service conception rate (Butler and Smith, 1989).

There is a time lag between when a cow experiences a severe negative energy balance or nutritional disturbance and when the greatest impact is seen in regard to reproductive performance. This time lag occurs because of the 60 to 100 day period required from the time a follicle within the ovary is activated to begin development until the time the follicle is mature and ready to ovulate. As embryonic health is influenced by the follicular endocrine milieu, follicles growing during early lactation or at peak milk production, may produce oocytes and embryos of lower quality.

The studies presented here examined the effects of genetic merit for milk production, breed and prepartum feeding on reproductive performance in dairy cows.

3. Effect of breed of dairy cow on reproductive performance

Materials and Methods

Animals

High genetic merit HF (HGM), medium genetic merit HF (MGM), Montbeliarde (MB) and Normande (NM) cows were studied over a period of four years. Both the MB and the NM are dual-purpose breeds (selected for both milk and beef production), while the HGM and the MGM were selected only on milk production. The HGM cows had 94 (± 2.5) % Holstein-Friesian genes. The average expected genetic merit (± SD) in early 1996 for milk yield of the MB, NM and HGM cows were on a heifer basis and were expressed as a deviation from the respective herd and breed averages. Breed averages were +588 (± 349) kg, +539 (± 177) kg and +540 (± 219) kg, for HGM, MB and NM breeds respectively. There were insufficient ancestry data to put a precise index on the MGM breed, but at least three generations of HF sires were used. In year 1, all cows were in their second lactation, while in year 2, 3 and 4, cows culled were replaced with first lactation cows. The first lactation cows were the progeny of the respective breeds.

Feeding system

Over the four years of study all four breeds were managed as one herd. Post calving and prior to turnout to pasture (late February - early March), cows were offered 5 kg of concentrate daily (ME = 12.3 MJ ME/kg DM, CP = 24.1 % DM) plus 2.5 kg DM of pressed pulp. Post turnout, cows were grazed on a rotational management system. Immediately post turnout, cows were offered 5 kg of concentrate daily. Over the total lactation the level of concentrate offered per cow was approximately 600 kg. Over the 14 weeks of the breeding season (late April to early August) the average daily concentrate offered per cow was approximately 1.7 kg. Concentrates were offered as two equal feeds to cows while in individual stalls in the milking parlour.

Significant breed differences in cow fertility were detected

Milk production and body condition

Milk yield and composition were recorded once per week. Body weights were recorded every 2 weeks. Body condition score, on a scale from one to five, was measured every 3 to 4 weeks.

Breeding management

Cows were inseminated over a period of 14 weeks, starting at the end of April. Artificial insemination was used for the first 10 weeks of the breeding period and a stock bull was used for the remaining 4 weeks of the breeding season. Tail paint was used as an aid to heat detection. Pregnancy diagnosis was performed by ultrasonography 30 to 40 days after service and by rectal palpation 6 weeks after the end of the breeding season.

Results

Effect of breed of dairy cow on milk production and body condition

The HGM cows had significantly higher milk production compared with cows of the other 3 breeds (P < 0.05, Table 1). Furthermore, HGM and NM cows had higher milk fat percentage than MGM cows (P < 0.05) and protein percentage was significantly lower for HGM and MGM cows compared with that of the MB and NM cows (P < 0.05), while that of NM cows was significantly higher than that for MB cows (P < 0.05). Body weight post calving of HGM cows was significantly less compared with that of the NM cows (P < 0.05), but the difference was not significant compared with the MGM and MB cows (P > 0.05). Body weight loss between calving and first service was significantly greater for HGM cows compared to MB cows (P < 0.05). The HGM and MGM cows had a significantly lower BCS post calving than MB and NM cows (P < 0.05). In addition, HGM cows lost significantly more condition between calving and first service than MB and NM cows (P < 0.05).

Table 1 Milk production (238 d), milk composition, body weight and body condition score (ls-mean ± SEM) in Dutch (HGM), Irish Holstein-Friesian (MGM), Montbeliarde (MB) and Normande cows (NM)[1]

Breed		**HGM**	**MGM**	**MB**	**NM**
Milk production	(kg)	5319 ± 100.1^{a}	4793 ± 98.8^{b}	4609 ± 97.5^{b}	4086 ± 97.4^{c}
Milk composition	(%)				
fat		$3.88 \pm 0.05^{a,b}$	3.72 ± 0.05^{c}	3.85 ± 0.05^{b}	3.99 ± 0.05^{a}
protein		3.36 ± 0.03^{c}	3.35 ± 0.03^{c}	3.51 ± 0.03^{b}	3.59 ± 0.03^{a}
Body weight:					
post calving	(kg)	525 ± 7.91^{b}	522 ± 7.79^{b}	$538 \pm 7.42^{a,b}$	553 ± 7.40^{a}
change from calving to 1st AI	(kg/day)	-0.27 ± 0.06^{b}	$-0.17 \pm 0.06^{a,b}$	-0.10 ± 0.06^{a}	$-0.12 \pm 0.06^{a,b}$
Body condition score:					
post calving		2.82 ± 0.05^{c}	3.00 ± 0.05^{b}	3.30 ± 0.05^{a}	3.27 ± 0.05^{a}
change from calving to 1st AI		0.31 ± 0.06^{b}	$-0.17 \pm 0.06^{a,b}$	-0.10 ± 0.06^{a}	

a, b, c *Values that do not share superscripts within rows differ (P<0.05)*
1 *HGM, MGM, MB and NM, n = 25 - 28 in year 1 to 4*

Effect of breed of dairy cow on reproductive performance

Reproductive performance was not significantly different between year 1, 2, 3 and year 4 ($P > 0.05$). Therefore, the data for the four years were combined for analyses.

Calving date and calving to service interval were not significantly different between breed types ($P > 0.05$, Table 2). Less HGM cows were submitted for service in the first three weeks of the breeding season compared with MB cows ($P < 0.05$), the difference between HGM and MGM and NM cows was not significant. The calving to conception interval was significantly longer for the HGM cows compared with MB and NM cows ($P < 0.05$). Whereas the pregnancy rates to each service did not differ significantly between breeds, significantly more HGM cows were not pregnant at the end of the breeding season compared with cows of the other breeds ($P < 0.05$). Although the number of services per conception in cows that conceived during the defined breeding season did not differ between the four breeds ($P > 0.05$), overall, significantly more services were required per conception for the HGM breed compared with the MB and NM breeds ($P < 0.05$).

Table 2. Calving day of year, calving to service interval, submission rate, calving to conception interval, pregnancy rates and number of services (ls-mean ± SEM) in Dutch (HGM), Irish Holstein-Friesian (MGM), Montbeliarde (MB) and Normande cows (NM)[1]

Breed		HGM	MGM	MB	NM
Calving day of year	(Julian date)	58.7 ± 3.43	57.0 ± 3.43	58.7 ± 3.39	61.0 ± 3.39
Calving to service interval	(days)	72.6 ± 2.71	71.6 ± 2.70	66.8 ± 2.68	68.7 ± 2.67
Submission rate (3 wk)	% (No.)	73.4(80/109)[b]	85.3 (93/109)[a,b]	89.0 (97/109)[a]	82.6 (90/109)[a,b]
Calving to conception interval	(days)	97.3 ± 3.92[a]	87.0 ± 3.68[ab]	84.2 ± 3.54[b]	85.1 ± 3.51[b]
Pregnancy rate	%(No.)				
Overall		73.4(80/109)[b]	87.2 (95/109)[a]	90.8 (99/109)[a]	89.9 (98/109)[a]
1st service		39.5 (43/109)	45.0 (49/109)	47.7 (52/109)	55.1 (60/109)
2nd service		41.7 (25/60)	45.6 (26/57)	46.4 (26/56)	43.5 (20/46)
3rd to 5th service		46.4 (13/28)	66.7 (20/30)	75.0 (21/28)	78.3 (18/23)
Services per pregnant cow	(No.)	1.73 ± 0.11	1.78 ± 0.10	1.76 ± 0.10	1.63 ± 0.09
Services per conception per breed	(No.)	2.69 (215/80)[a]	2.25 (214/95)[a,b]	2.08(206/99)[b,c]	1.88 (184/98)[c]

a, b, c *Values that do not share superscripts within rows differ (P<0.05)*
1 *HGM, MGM, MB and NM, n = 25 - 28 in year 1 to 4*

Association between production parameters and pregnancy rate to first service

Cows that did not conceive to first service were retrospectively compared to cows that conceived to first service (Table 3). Cows that did not conceive had higher milk production compared with cows that conceived to first service ($P < 0.05$). However, when cows that did not conceive were compared with cows that conceived to first service, within breed, milk production did not differ significantly between cows that did conceive and those that did not conceive to first service ($P < 0.05$). Furthermore, milk composition and body condition score post calving and change in BCS between calving and first service did not differ significantly between cows that did not conceive and cows that conceived to first service ($P > 0.05$).

Table 3. Milk production (238 d), milk composition and body condition (ls-mean+SEM) for cows that did or did not conceive to first service

Pregnancy status		**Did not conceive**	**Conceived**
Milk production	(kg)	4891 ± 65.6a	4653 ± 69.7b
Milk composition	(%)		
fat		3.84 ± 0.03	3.86 ± 0.03
protein		3.44 ± 0.02.	3.47 ± 0.02
Body condition score:			
post calving		3.06 ± 0.04	3.14 ± 0.04
change from calving to first service		-0.17 ± 0.03	-0.20 ± 0.03

[a, b] ***Values that do not share superscripts within rows differ ($P<0.05$)***

4. Effect of genetic merit for milk production in Holstein-Freisian cows on ovarian follicular dynamics and reproductive performance

Materials and Methods

Animals

High (90% Holstein-Friesian genes, 80-100%), (HGM) and medium genetic merit (50% Holstein-Friesian genes, 12-75%), (MGM) cows were used in a study conducted over two years (HGM n = 48 in year 1 and n = 46 in year 2; MGM n = 48 in year 1 and 2). The mean predicted difference (PD' 95) ± standard deviation for milk production was + 475 (± 76) kg for the HGM cows and + 140 (± 68) kg for the MGM cows. The cows calved between January and April in each year. In year 2, first lactation cows of similar genetic merit replaced 25% of both HGM and MGM cows culled at the end of year 1.

Feeding systems

From calving until turnout to pasture in March, all cows were offered grass silage ad libitum and 9 kg/d of dairy concentrates (ME = 12.5 MJ ME/kg DM, CP = 20.1% DM). The concentrates were offered as two equal feeds to cows while in individual stalls in the milking parlour. After turnout, an equal number of cows of each genetic merit were allocated to one of three feeding systems: (1) a control system, which had a stocking rate of 3 cows/ha with an input of 380 kg nitrogen/ha, and a supplementation level of 1.5 kg of concentrates/cow/day during the breeding period; (2) a high concentrate input system, in which the stocking rate and nitrogen inputs were the same as in (1), but with a supplementation level of 4.0 kg of concentrates/cow/day during the breeding period, (3) a high grass allowance system, in which the nitrogen and concentrate supplementation levels were the same as in (1), but where unrestricted access to high quality grass was available to cows. Cows were managed on a rotational grazing system on high quality perennial ryegrass-type swards.

Pregnancy rate was significantly lower in high genetic merit cows

Milk production and body condition

Milk yield was recorded on five consecutive days per week. Body weights were recorded weekly and BCS, on a scale from one to five, was assessed every 3 to 4 weeks.

Ovarian ultrasonography

In year 1, both ovaries of 10 HGM and 12 MGM cows were examined daily, from day 7 to 40 postpartum, by ultrasonography.

Breeding management

Cows were inseminated during a breeding period of 13 wk, starting in late April and finishing in late July of each year. Pregnancy diagnosis was performed by ultrasonography 30 to 40 day after service and again by rectal palpation 6 weeks after the end of the breeding season.

Results

Effect of genetic merit on milk production, body condition and feed intake

High genetic merit cows had higher ($P < 0.05$) milk production at time of first service and higher cumulative 120-day milk production than did MGM cows (Table 4). Body weight at calving and daily change in body weight from calving to first service did not differ between HGM and MGM cows ($P > 0.05$). However, BCS at calving was lower for HGM than for MGM cows and HGM cows lost more body condition from calving to first service than did MGM cows ($P < 0.05$).

Table 4. Milk production, body weight, and body condition score (ls-mean ± SEM) in high and medium genetic merit dairy cows[1]

Genetic merit		HGM	MGM
Milk production at 1st service	(kg/day)	34.6 ± 0.64^a	31.0 ± 0.64^b
over 120 days	(kg)	3819 ± 65.2^a	3433 ± 64.5^b
Body weight at calving	(kg)	576 ± 6.46	573 ± 6.48
change from calving to 1st AI	(kg/day)	-0.42 ± 0.06	-0.42 ± 0.06
Body condition score (BCS) at calving		2.88 ± 0.05^b	3.31 ± 0.05^a
change from calving to 1st AI		-0.47 ± 0.05^b	-0.23 ± 0.05^a

a, b Values that do not share a common superscript within rows differ (P<0.05)

1 HGM, n=48 in Year 1 and n=46 in Year 2; MGM, n=48 in Year 1 and n=48 in Year 2.

Effect of genetic merit on ovarian follicular dynamics

Eight out of ten HGM and seven out of twelve MGM cows ovulated within the 40-day period of ultrasonic scanning ($P > 0.05$). Eight HGM cows and four of the MGM cows ovulated twice within this period ($P < 0.05$). Cycle length for six HGM and three MGM cows was normal (20 to 24 d). One MGM cow developed a cyst, two HGM and four MGM cows did not ovulate within the 40-day period. High and medium genetic merit cows showed no difference ($P > 0.05$) in the ls-mean (SEM) growth rate of the ovulatory follicle, size of first ovulatory follicle or the day of first ovulation (daily growth rate: 2.60 (± 0.29) vs. 2.07 (± 0.29) mm, size of ovulatory follicle: 19.3 (± 0.81) vs. 19.1 (± 0.87) mm, day of ovulation: 18.1 (± 2.28) vs. 19.7 (± 2.44) d postpartum, respectively).

Effect of genetic merit on reproductive performance

Reproductive performance was not significantly different between year 1 and year 2 ($P > 0.05$). Furthermore, feeding system did not affect reproductive performance in either year ($P > 0.05$). Therefore, the data of the two years were combined for final statistical analyses.

HGM and MGM cows (Table 5). However, more HGM than MGM cows were not pregnant at the end of the breeding period. Furthermore, conception rates to the first ($P = 0.09$), second and fourth service and overall conception rates were significantly lower for HGM than for MGM cows ($P < 0.05$). The number of services per conception in cows that conceived during the defined breeding season did not differ significantly between HGM and MGM cows ($P > 0.05$), but overall, more services were required per conception for the HGM category compared with the MGM category ($P < 0.05$).

Table 5. Calving day of year, submission rate calving to service interval, calving to conception interval, pregnancy rate and number of services per conception (ls-mean ± SEM) in high and medium genetic merit dairy cows1

Genetic merit		**HGM**	**MGM**
Calving day of year	(Julian Date)	53.3 ± 2.99	53.2 ± 2.96
Submission rate	(%)	83.1 (78/96)	87.5(84/96)
Calving to 1st service interval	(days)	72.4 ± 2.49	70.3 ± 2.46
Calving to conception interval	(days)	90.5 ± 3.34	90.6 ± 3.01
Pregnancy rate	% (No.)		
Overall		77.7 (73/94)b	93.8 (90/96)
1st service		41.5 (39/94)d	52.1 (50/96)c
2nd service		40.0 (22/55)b	58.7 (27/46)a
3rd service		37.0 (10/27)	27.8 (5/18)
4th service		15.4 (2/13)b	60.0 (6/10)a
5th service		33.3 (2/6)	100 (2/2)
Services per conception, (pregnant cows),	(No.)	1.75 ± 0.11	1.70 ± 0.11
Services per pregnancy	(No.)	2.67 (195/73)a	1.91(170/90)b

a, b ***Values that do not share a common superscript within rows differ (P<0.05)***
c, d ***Differ (P=0.09)***
1HGM, n = 48 in year 1 and n = 46 in year 2; MGM n = 48 in year 1 and n = 48 in year 2

Association between production parameters and pregnancy rate to first service

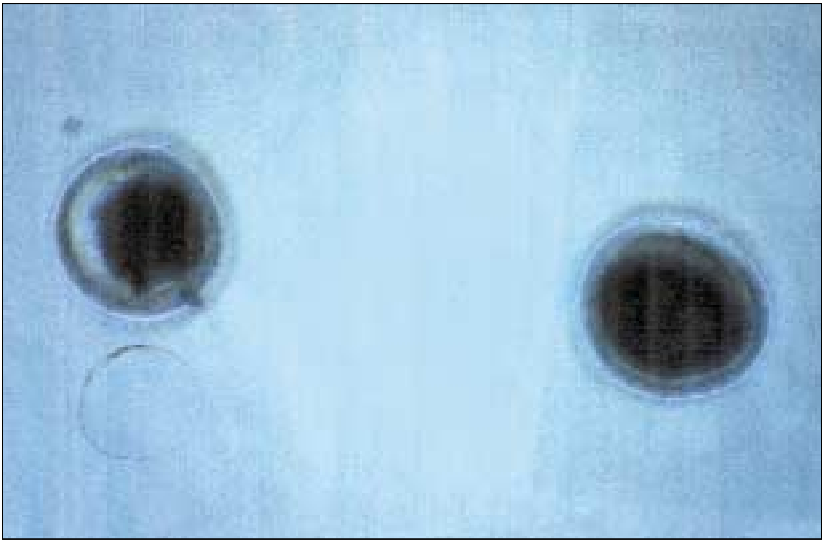
Cows were retrospectively allocated to two categories, within each genetic merit: cows that did not conceive and cows that conceived to first service (Table 6). Calving to service interval was significantly shorter ($P < 0.05$) for HGM cows that did not conceive than for HGM cows that conceived to first service. Milk production of cows that did not conceive to first service was not significantly different from that of cows that conceived to first service within either genetic merit category ($P > 0.05$). Body condition loss from calving to first service was not significantly different between HGM cows that did not conceive and HGM cows that conceived to first service ($P > 0.05$).

Table 6. Differences in calving day of year, calving to service interval, milk production and body condition (ls-mean ± SEM) for high (HGM) and medium (MGM) genetic merit dairy cows that conceived or did not conceive to first service[1]

Pregnancy status		Did not conceive	Conceived
High genetic merit			
Calving day of year	(Julian date)	59.5 ± 3.65[c]	49.3 ± 4.37[d]
Calving to first service interval	(days)	65.7 ± 3.12[a]	77.7 ± 3.73[b]
Milk production over 120 days	(kg)	3838 ± 79.4	3843 ± 94.9
Body condition score (BCS) at calving		2.90 ± 0.06	2.89 ± 0.07
change from calving1st AI		-0.47 ± 0.06	-0.50 ± 0.07
Medium genetic merit			
Calving day of year	(Julian date)	52.7 ± 5.95	56.2 ± 4.11
Calving to service interval	(days)	68.5 ±5.08	68.8 ± 3.51
Milk production over 120 days	(kg)	3582 ± 129.	33458 ± 89.4
Body condition score (BCS) at calving		3.28 ± 0.09	3.38 ± 0.07
change from calving -1st AI		-0.27 ± 0.09[a]	-0.14 ± 0.07[b]

Values that do not share a common superscript within rows differ

***a, b** (P<0.05)*
***c, d** (P=0.08)*
***1** Did not conceive (HGM: n = 30 in year 1, n = 25 in year 2; MGM: n = 22 in year 1, n = 24 in year 2) ; conceived to first service (HGM: n = 18 in year 1, n = 21 in year 2; MGM: n = 26 in year 1, n = 24 in year 2)*



Emlugo development was poorer in high genetic merit cows

5. Effect of genetic merit for milk production in Holstein-Freisian cows on oocyte development

Materials and Methods

Animals

All high and medium genetic merit cows in either their first or third lactation from Experiment 2 were slaughtered for reasons related to a national disease control program, on September 1st. At the time of slaughter, 16 cows were not pregnant (HGM n = 13, of which 4 cows in their first lactation, MGM n = 3, of which 1 cow in her first lactation). The data from 94 cows were used in the analyses.

In vitro maturation, fertilisation and culture of oocytes

Ovaries were collected at slaughter and transported to the laboratory in phosphate buffered saline (PBS). Ovarian follicles (2 - 10 mm) were aspirated between 3 and 7 h after slaughter. Maturation, fertilisation and culture were carried out according to the methods described by O'Doherty *et al* (1997). All oocytes were inseminated with semen from a single ejaculate; this semen was used on a regular basis in IVF in this laboratory. Capacitated sperm cells, at a concentration of 1 to 1.5 million/ml, were added to the oocytes. Oocytes from one cow were placed in one culture well and were incubated with spermatozoa for 24 h. Then, presumptive zygotes were washed 3 times in medium. The presumptive zygotes were incubated in a humidified atmosphere of 5% CO_2 in air at $38.5^{o}C$. Cleavage and blastocyst formation rates were recorded 44 h and 7 d after insemination, respectively.

Effect of genetic merit on oocyte development *in vitro*

Data in Table 7 show the effect of genetic merit on number of oocytes recovered and rates of cleavage and development to blastocysts. The number of cows yielding oocytes did not differ significantly ($P > 0.05$) between genetic merit groups (HGM: 48, MGM: 45). However, fewer ($P < 0.05$) HGM than MGM cows (11 vs 20, respectively) yielded oocytes resulting in blastocysts. In turn, oocytes from HGM cows yielded fewer blastocysts and had lower rates of cleavage and blastocyst formation (from total oocytes cultured) than those from MGM cows ($P < 0.05$).

Effect of lactation number on milk production and oocyte development *in vitro*

Cows in first lactation had lower ($P< 0.05$) milk production and body weights than those in their third lactation (Table 8). However, BCS at oocyte recovery did not differ significantly ($P > 0.05$) between cows in their first and their third lactation.

Cows in their first lactation yielded fewer ($P = 0.08$) oocytes than cows in their third lactation (Table 9). Furthermore, oocytes from HGM cows in their first lactation yielded no blastocysts and oocytes from all cows in their first lactation yielded fewer blastocysts ($P = 0.08$) and had lower blastocyst formation rates ($P < 0.05$) than those from cows in their third lactation.

Table 7. The effect of genetic merit on numbers of oocytes recovered and their subsequent cleavage and development to blastocysts (ls-mean ± SEM) in high (n=48) and medium genetic merit (n=46) dairy cows

Genetic merit		**HGM**	**MGM**
Oocytes collected/cow	(No.)	6.7 ± 0.75	7.6 ± 0.91
Cleavage rate %	(No.)	70.4 (238/338)[a]	77.4 (278/359)[b]
Blastocysts per cow	(No.)	0.36 ± 0.19[a]	0.85 ± 0.22[b]
Blastocyst formation rate %	(No.):		
from oocytes cultured		6.8 (23/338)[a]	11.4 (41/359)
from cleaved oocytes		9.7 (23/238)	14.7 (41/278)

Values with different superscripts within rows differ ***a, b(P<0.05)***

Table 8. The effect of lactation number on milk yield, body weight and body condition score (BCS) in first (n=24) and third lactation (n=70) dairy cows (ls-mean ± SEM)

Lactation number	**First**	**Third**
Days postpartum	177 ± 3.50	176 ± 2.22
Milk yield at oocyte recovery(kg/day)	19.4 ± 0.87[a]	25.6 ± 0.55[b]
Milk yield over 120 days(kg)	3087 ± 102.1[a]	4238 ± 64.79[b]
Body weight at oocyte recovery(kg)	507 ± 11.00[a]	599 ± 6.98[b]
BCS at oocyte recovery	2.75 ± 0.11	2.91 ± 0.07

Values with different superscripts within rows differ a, b(P<0.05)

Table 9. The effect of lactation number on numbers of oocytes recovered and their subsequent cleavage and development to blastocysts (ls-mean ± SEM) in first (n=24) and third lactation (n=70) dairy cows

Lactation number		First	Third
Oocytes collected/cow	(No.)	5.7 ± 1.24c	7.8 ± 0.79d
Cleavage rate %	(No.)	73.8 (96/130)	74.1 (420/567)
Blastocysts/cow	(No.)	0.23 ± 0.31c	0.76 ± 0.20d
Blastocyst formation rate %	(No.):		
from oocytes cultured		3.9 (5/130)a	10.4 (59/567)b
from cleaved oocytes		5.2 (5/96)a	14.0 (59/420)b

Values with different superscripts within rows differ a, b($P<0.05$) c, d($P=0.08$)

Effect of milk production on oocyte development *in vitro*

The effect of 120 d milk production was tested by comparing the 20 lowest (HGM n = 7, MGM n = 13) with the 20 highest (HGM n = 16, MGM n = 4) cows in the third lactation (Table 10). There was no difference in days in lactation between cows of the two groups ($P > 0.05$). The number of oocytes yielded and rates of cleavage and blastocyst formation did not differ significantly ($P > 0.05$) between cows assigned to the high and low milk production group.

Table 10. The effect of 120 d milk production on numbers of oocytes recovered and their subsequent cleavage and development of blastocysts (ls-mean ± SEM) in dairy cows

120 d milk yield (kg)		3162 - 3972	4559 - 5114
Days in lactation at slaughter (range)		178 ± 4.35	173 ± 4.42 (130 - 228)
		(142 - 220)	173 ± 4.42 (130 - 228)
Oocytes collected	(No.)	8.9 ± 1.32	6.9 ± 1.34
Cleavage rate %	(No.)	69.1 (125/181)	65.6 (85/129)
Blastocysts	(No.)	0.68 ± 0.39	0.87 ± 0.39
Blastocyst formation rate %	(No.):		
from oocytes cultured		9.9 (18/181)	10.1 (13/129)
from cleaved oocytes		14.4 (18/125)	15.3 (13/85)

The effect of body condition on oocyte development *in vitro*

The effect of BCS at time of oocyte recovery was tested by comparing the 20 lowest (HGM n = 19, MGM n = 1) with the 20 highest (HGM n = 2, MGM n = 18) cows in their first or third lactation (Table 11). The numbers of oocytes recovered did not differ significantly ($P > 0.05$) between the two groups. However, cleavage and blastocyst formation rates (from total oocytes cultured) for oocytes from cows with lower BCS were significantly smaller ($P < 0.05$) than for those from cows with higher BCS.

Table 11. The effect of body condition score at slaughter on number of oocyte recovered and the subsequent cleavage and development to blastocysts (ls-mean ± SEM) in dairy cows

Body condition score		1.5 - 2.5	3.3 - 4.0
Oocytes collected	(No.)	7.0 ± 1.80	8.5 ± 1.48
Cleavage rate %	(No.)	61.9 (83/134)a	75.7 (115/152)b
Blastocysts	(No.)	0.14 ± 0.37	0.78 ± 0.30
Blastocyst formation rate %	(No.)		
from oocytes cultured		3.0 (4/134)a	9.9 (15/152)b
from cleaved oocytes		4.8 (4/83)	13.0 (15/115)

Values with different superscripts within rows differ a, b P<0.05)

6. Effect of Prepartum feeding on embryo quality in Holstein-Freisian cows

Materials and Methods

Animals and feeding treatments

Spring-calving Holstein-Friesian cows (n=54) were randomly allocated to one of two grass silage-based diets: (1) grass silage to appetite and 3 kg concentrates from 5 wk before calving, or (2) mixture of 75% grass silage, as in (1), and 25% barley straw. At nine weeks before the expected calving date, cows were dried off and allocated to the diets, based on their expected calving dates, lactation group (lactation number 2, ≥ 3) and BCS two weeks before drying off. The dietary allowance was group-fed. After calving, all cows received a single grass silage diet and 8 kg of concentrates. Concentrates were offered as two equal feeds to cows while in the milking parlour.

Although cows ovulated early after calving , embryo quality was poor

Milk production, feed intake and body condition

Milk production was recorded twice daily every week. Feed intake of each cow was estimated on wk 6 and 3 prepartum and wk 4 postpartum, using the n-alkane technique. Body weight, BCS, and back-fat depths were determined every two weeks pre calving and weekly post calving until d 80. Back fat depths were determined by ultrasonography. Body condition score was determined on a scale from one to five.

Ovarian ultrasonography

The ovaries of all cows were examined daily, between d 7 postpartum and first ovulation, by transrectal ultrasonography. Ultrasound images of follicle populations were mapped to determine the timing of first ovulation, necessary to plan embryo recovery.

Embryo collection and staining

Seven days after first ovulation, an intra-muscular injection of PGF_{2a} (2.5 ml Estrumate) was given to all cows and tail paint was applied to all cows. Cows that were observed in oestrus within two or three days of injection were inseminated, using frozen–thawed semen. The same inseminator conducted inseminations and the same sire was used for all inseminations. Cows that were not observed in oestrus received a second PGF_{2a} injection, one week after first injection and inseminated when in standing oestrus. Five to nine days after insemination, embryos were collected non-surgically. If an embryo was not found, cows were injected with PGF_{2a} and they were inseminated when in standing oestrus. Embryo collection was conducted twice if no embryo was found at the first collection or until 100 days postpartum.

For estimation of the total number of cells, embryos were stained and visualised with an epifluorescence microscope (Zeiss, Oberkochen). Embryos were scored according to the total cell number and their quality was classified as normal or abnormal (Table 12). Quality was based on reports by Dorn and Kraemer (1987) of stage of development at day post insemination and Van Soom (1996) on total cell number for different developmental stages of *in vivo* produced embryos.

Table 12. Normal embryos, classified on total cell number (range) on days post insemination (Dorn and Kraemer, 1987; Van Soom, 1996)

Days post insemination	Total cell number	No. of embryos
5	11 – 17	16
6	26 – 88	32
7	82 – 128	18
8	145 – 173	12
9	149 – 210	14

Results

Effect of prepartum feeding treatment on milk production, body condition and feed intake pre- and postpartum

Milk production at first embryo collection or over the first trimester of lactation was not affected ($P > 0.05$) by prepartum feeding treatment (Table 13). Furthermore, body weight at the start of the dry period and at calving was not different between cows fed silage and concentrates or cows fed silage and straw ($P > 0.05$). However, cows fed silage and concentrates had significantly ($P < 0.05$) higher BCS at calving than cows fed silage and straw. Cows fed silage and concentrates gained more condition from 9 and 5 wk prepartum to calving and had higher BCS at time of first embryo collection, compared with cows fed silage and straw ($P < 0.05$). On the other hand, cows fed silage and concentrates had lower feed intake at 6 weeks ($P < 0.05$) and 3 weeks ($P = 0.07$) prepartum compared with cows fed silage and straw. However, the difference in feed intake postpartum between cows of the two treatments was not significant ($P > 0.05$).

Table 13. Effect of prepartum feeding treatment on milk production, body weight, body condition, and feed intake (ls-mean ± SEM)

Prepartum feeding treatment	Silage/concentrates (n = 27)	Silage/straw (n = 27)
Milk production		
At first embryo collection (kg/day)	26.1 ± 0.60	26.2 ± 0.60
Over 100 days(kg)	2492 ± 53.7	2383 ± 53.7
Body weight (kg)		
At 9 wk prepartum	609 ± 12.5	612 ± 13.0
At calving	618 ± 13.5	591 ± 14.0
Body condition score[1]		
At 9 wk prepartum	2.73 ± 0.07	2.74 ± 0.07
Change from 9 wk prepartum to calving	0.31 ± 0.10e	0.06 ± 0.10f
Change from 5 wk prepartum to calving	0.17 ± 0.07a	-0.06 ± 0.07b
At calving	3.01 ± 0.07a	2.79 ± 0.07b
At first embryo collection	2.83 ± 0.08	2.79 ± 0.07b
Change from calving-embryo collection	-0.21 ± 0.09	-0.09 ± 0.10
Feed intake (kg/day)		
6 wk prepartum	8.18 ± 0.35b	9.76 ± 0.38a
3 wk prepartum	8.39 ± 0.33d	9.88 ± 0.36c
3 wk postpartum	14.9 ± 0.31	15.2 ± 0.33

Values with a different superscript within rows differ
a, b (P<0.05)
c, d (P=0.07)
e,f (P=0.09)
1On a scale from one to five

Effect of prepartum feeding treatment on day of first ovulation and embryo recovery

The days of first ovulation and first embryo collection were not significantly different ($P > 0.05$) between cows fed silage and concentrates (ovulation: 22.1 (± 2.06), range: 11 - 51, n = 23; day of first embryo collection: 49.3 (± 2.72), range: 31 - 69, n = 23) compared with those fed silage and straw (ovulation: 17.7 (± 1.99), range: 9 - 38, n = 24; day of first embryo collection: 45.7 (± 2.52), range: 31 - 72, n = 25). The number of ova collected did not differ significantly between cows of the two prepartum feeding treatments. Although the number of fertilised ova and normal embryos collected was low, they did not differ significantly between silage and concentrate-fed and silage and straw-fed cows (Table 14). In addition, there was no significant difference in cell number of morulas collected from cows fed silage and concentrates or from those fed silage and straw.

Table 14. Effect of prepartum feeding treatment on number of cows yielding ova, fertilised ova and normal embryos (based on cell number), collected after first or second embryo collection

Prepartum feeding treatment		Silage/conc. (n=27)	Silage/straw (n=27)
Cows flushed	(No.)	24	26
Cows yielding ova or embryos	(No)	17	19
Ova fertilised	%(No.)	64.7 (11/17)	78.9 (15/19)
Normal embryos	%(No.)	18.2 (2/11)	33.3 (5/15)
Morula cell No.;			
ls-mean±SEM	(range, No.)	39 ± 4.46 (28 – 53, 6)	40.3 ± 2.28 (30 - 51, 9)
Embryos < 16 cells	%(No.)	0 (0/11)	13.3 (2/15)

Differences were not significant (P>0.05)

Associations between embryo quality and milk production, body condition and feed intake

Correlations were estimated between embryo quality and milk production, body condition and feed intake (Table 15). Embryo quality tended to be negatively correlated with cumulative 100-day milk production (P = 0.09). It was positively correlated with feed intake prepartum (P < 0.01), but not with body condition (P>0.05).

Table 15. Correlations between embryo quality (across treatments) and milk production, body condition score and feed intake

	Embryo quality	
Statistics	**CC[1]**	**P value**
Milk production		
At embryo collection[2]	-0.15	0.66
Cumulative 100-day yield	-0.53	0.09
Body condition score		
At calving	0.05	0.88
Nadir of BCS	-0.22	0.51
At embryo collection[2]	-0.49	0.15
Feed intake		
6 weeks prepartum	0.15	0.01
3 weeks prepartum	0.73	0.01
4 weeks postpartum	0.30	0.37

1 Pearson correlation coefficient
2 At time of first and second embryo collection

8. Conclusions and Implications

The results from Experiment 1 show that high genetic merit Holstein-Friesian cows had lower fertility than the dual-purpose breeds examined. Given the increased use of Holstein-Friesian genetics in the Irish dairy industry, these results have serious implications for future national dairy herd fertility. Crossbreeding with fertile dual-purpose breeds should be considered an option to improve dairy herd fertility.

The results from Experiment 2 show that despite significant differences in milk production and fertility between high and medium merit Holstein-Friesian animals, cows that conceived to first service did not differ in milk yield from those that did not conceive. These results imply that increased milk production *per se* is not associated with reduced fertility in high genetic merit cows.

The results from Experiment 3 show that while oocyte quality was reduced in cows of high genetic merit, cows in low body condition and cows in first lactation, oocyte quality was unaffected by milk production. These results suggest that reduced oocyte quality is likely to contribute to reduced fertility in high genetic merit cows, in particular younger cows and those in poor body condition.

The results from Experiment 4 show that although cows may ovulate early, embryo quality is poor in the early postpartum period. These results suggest that dairy cow feeding and management during the dry and transition periods may need to be altered to impact positively on folliculogenesis and embryo competence during the breeding season.

Genetic selection of dairy cows for increased milk production has been associated with reduced reproductive performance. Results from abroad concluded that the increased proportion of Holstein genes in dairy cows contributed to the severe decline in the reproductive performance.

Despite these negative genetic associations between milk production and reproduction, reproduction in high producing dairy herds is not necessarily compromised relative to reproduction in low producing dairy herds. This is because high-producing herds may have better nutritional and reproductive management. Therefore, good reproductive management of high producing dairy herds may partially overcome the antagonistic genetic relationship between milk production and reproduction.

In the present experiments, the high proportion of Holstein-Friesian genes played a more important role in the decreased reproductive performance than milk production *per se*. The potential benefits of crossbreeding with 'fertile' dual-purpose breeds in the dairy herd are highlighted.

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