Phenotypic relationships between milk protein percentage and reproductive performance in three strains of Holstein Friesian cows in Ireland

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ABSTRACT

The relationship between milk protein percentage and fertility in seasonal calving, dairy cattle in Ireland was quantified using a total of 584 lactation records, collected over a five-year period from experiments comparing three strains of Holstein-Friesian cows under three different feeding systems. Logistic regression analyses showed that increased protein percentage during early lactation was positively associated with the probability of a cow becoming pregnant to its first service ($P < 0.05$). Similarly, protein percentage during the lactation had a positive ($P < 0.01$) association with overall pregnancy rate. The results suggest that negative energy balance in early lactation or during the whole lactation causes a shortage of glucose to the udder, this restricts the synthesis of milk protein in the udder and causes a lower milk protein percentage. During negative energy balance there is also a concurrent reduction of IGF-I, LH and oestradiol secretion, which consequently delay ovarian follicular development, and hence impairs reproductive performance. In conclusion, cows with higher milk protein percentage during early lactation have a greater likelihood of becoming pregnant earlier in the breeding season, and have a higher conception rate.

Keywords: milk protein percentage; fertility; negative energy balance.

INTRODUCTION

Protein percentage in milk is closely related to the level of energy balance (Buckley *et al*., 2003; Patton *et al*., 2007). Negative energy balance (NEB), especially in early lactation, has been shown to be associated with reduced fertility in lactating dairy cows (Butler, 2005). Fulkerson *et al*. (2001) showed that cows with low milk protein percentage suffered from more severe and prolonged NEB compared to cows with higher milk protein percentage. A higher likelihood of culling was also found in cows with a lower milk protein percentage than in cows with higher protein percentage in milk (Tena-Martínez *et al*., 2009). Postpartum NEB is associated with decreased milk protein percentage which is proposed to occur as a result of the shortage of glucose, which is used in the synthesis of milk protein in the udder (de Vries & Veerkamp, 2000).

Milk protein percentage has been reported to be positively associated with cow fertility. Morton (2001) found that cows with a higher milk protein percentage in early lactation had a substantially better reproductive performance. Positive relationships were identified between milk protein percentage, conception rate and the onset of luteal function (Patton *et al*., 2007). In the study carried out by Fahey *et al*. (2003), the not-in-calf rate after a 21-week mating period was significantly higher for cows in the lowest quartiles for milk protein percentage compared to those in the highest quartiles. A significant positive relationship between milk protein percentage and fertility performance has also been reported in New Zealand dairy cattle (Harris & Pryce, 2004).

In all-year-around calving herds of New South Wales, the risk of sub-fertility in multiparous cows increased with lower milk protein percentage during the first four months of lactation or at the time of first service (Moss *et al*., 2002). A Belgian study (Opsomer *et al*., 2000) showed that cows had an increased risk of anoestrous if their average milk protein percentage during the first three months of lactation was low.

The objective of the study reported here was to study the relationship between milk protein percentage and different measures of fertility in dairy cattle in Ireland, using data from experiments comparing three strains of lactating Holstein-Friesian cows in a seasonally calving herd.

MATERIALS AND METHODS

The data used in this study were obtained from an experiment carried out at Moorepark Research Centre in the Republic of Ireland over a five-year period from 2001 to 2005, comparing three strains of Holstein-Friesian cows in three feeding systems (Horan *et al*., 2005; McCarthy *et al*., 2007).

Animals and feeding systems

The three strains of Holstein-Friesian (H-F) cows that were compared in the study were: high

TABLE 1: Mean (± standard deviation) productive and fertility traits of three strains of Holstein-Friesians cows under three feeding systems. MP = Moorepark feeding system; HC = High concentrate feeding system; HS = High stocking rate system.

Effect	High production genotype			High durability genotype			New Zealand genotype		
	MP	HC	HS	MP	HC	HS	MP	HC	HS
Number of lactations	61	63	63	67	67	67	65	65	65
Milk production									
Milk (kg/cow)	6,346 (1,135)	7,487 (1,135)	6,420 (1,006)	6,307 (1,024)	7,202 (1,114)	6,188 (1,019)	5,881 (1,034)	6,306 (1,165)	5,601 (906)
Fat (g/kg)	41.1 (4.3)	39.0 (3.4)	39.6 (4.3)	39.5 (2.7)	39.1 (3.8)	40.8 (3.9)	44.0 (3.0)	44.2 (3.7)	44.2 (3.3)
Protein (g/kg)	34.6 (1.7)	34.4 (1.8)	34.0 (1.8)	34.4 (1.4)	35.2 (2.0)	34.7 (1.9)	35.9 (1.6)	36.1 (1.7)	35.5 (2.2)
Lactose (g/kg)	46.7 (1.0)	47.6 (0.9)	46.8 (1.2)	46.9 (1.0)	47.2 (1.2)	46.9 (1.3)	47.2 (1.1)	47.8 (1.0)	47.0 (1.2)
Reproduction									
21-day submission rate (%)	77 (42)	78 (42)	74 (44)	94 (24)	91 (29)	77 (41)	86 (35)	91 (29)	84 (36)
First service conception rate (%)	46 (50)	49 (50)	46 (50)	58 (49)	51 (50)	48 (50)	57 (50)	70 (46)	53 (50)
Overall pregnancy rate (%)	70 (46)	76 (43)	78 (42)	95 (21)	86 (34)	74 (44)	91 (29)	94 (24)	89 (31)
Total services per cow	2.0 (1.2)	2.0 (1.1)	1.8 (1.0)	1.6 (0.9)	1.8 (1.0)	1.9 (1.1)	1.7 (0.9)	1.5 (1.0)	1.7 (0.9)

production North American (HP), high durability North American (HD) and New Zealand (NZ). The three feeding systems were: a high grass allowance feeding system which is typical of spring calving herds in Ireland (MP, control); a higher concentrate system (HC) and a higher stocking rate system (HS). A total of 99, 117, 117, 124 and 126 animals were used in Year 1, 2, 3, 4 and 5, respectively, divided between strains and feeding systems.

Statistical analysis

The association between milk protein concentration and fertility performance was determined using a logistic regression model in PROC GENOMD (SAS, 2005). The model included the fixed effect of year and lactation number as class effects, solid corrected milk, body condition score change and protein percentage as covariables and the random effect of cow to account for repeated measures on the same cow.

Predicted probability of success was calculated using the following model:

$$P = \frac{1}{1 + e^{-(\beta_0 + \beta_1 x_1 + \beta_2 x_2 \ldots \beta_k x_k)}}$$

where P is the probability of an animal becoming pregnant, in the range $0 \leq P \leq +1$. β_0 is a constant and β_k are the regression coefficients of the predictor variables.

RESULTS

Descriptive statistics

Descriptive statistics of milk production and fertility traits for each of the strains and feeding systems are given in Table 1. Amongst the different strains of H-F cows, HP cows had the highest milk yield while NZ cows had the lowest. However, the

FIGURE 1: Association between the probability of a cow becoming pregnant at first service and milk protein percentage in the first 60 days of lactation.

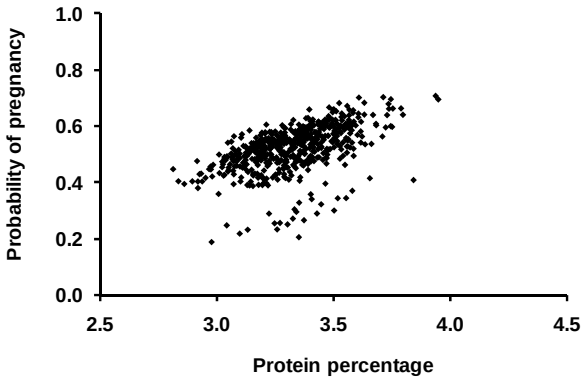
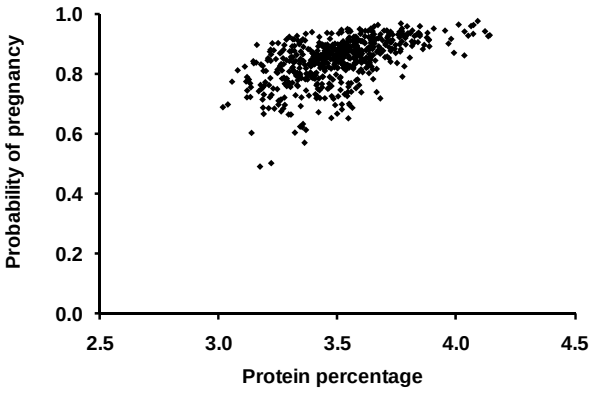


FIGURE 2: Association between the probability of a cow becoming pregnant during the whole breeding season and milk protein percentage during the lactation.



milk fat and protein percentage was greatest in NZ cows. HD cows had the highest 21-day submission rate, while NZ cows had the highest first service and overall pregnancy rates, and required fewer services to achieve a successful pregnancy. More details of the comparison amongst strains or feeding systems were given in Horan *et al*. (2005) and McCarthy *et al*. (2007).

Logistic regression analysis

Protein percentage in milk during the 60 days of the lactation had a positive ($P < 0.05$) association with pregnancy rate at first service (Figure 1). Additional analysis also showed similar relationships between probability of cows becoming pregnant at first service and early lactation milk protein percentage within each strain (L. Yang, Unpublished data). Similarly, protein percentage during the whole lactation had a positive ($P < 0.01$) association with overall pregnancy rate (Figure 2).

DISCUSSION

A positive relationship between milk protein percentage and reproductive performance has been reported in previous studies (Opsomer *et al*., 2000; Morton 2001; Moss *et al*., 2002; Buckley *et al*., 2003; Fahey *et al*., 2003; Harris & Pryce, 2004). The present study confirmed that protein percentage in milk was positively associated with cow fertility. The relationship between milk protein percentage and reproductive performance is probably mediated through energy balance and its effect on blood hormone and metabolites such as glucose. High milk production is associated with low glucose levels, and glucose shortage would result in a reduction of synthesis of milk protein; thus, low milk protein percentage would be found in cows with high milk production and low fertility. Morton (2000) suggested that the relationship between milk protein percentage and reproductive performance was influenced by nutritional strategies that may increase both milk protein percentage and reproductive performance.

The reduced milk protein synthesis which is caused by NEB could influence the anovulatory anoestrous periods through the mediating effect of IGF-I concentrations. Serum IGF-I concentrations are influenced by variations in protein synthesis or energy intake (Breukink & Wensing, 1998; Zulu *et al*., 2002), and IGF-1 is also an indicator of energy balance (Spicer *et al*., 1990). Severe NEB inhibits reproductive function through reduced LH pulse frequency, dominant follicle growth rate and diameter, concentrations of IGF-1, glucose and insulin and increased GH concentrations. All these changes would result in increased percentage of anoestrous cows (Roche *et al*., 2000). Cows with prolonged anovulatory anoestrous periods have lower submission and conception rates, and a higher culling rate for failure to conceive (Macmillan, 1997; Tena-Martínez *et al*., 2009). An early study showed that cows that displayed oestrus more than once before the first insemination had improved fertility compared to those inseminated at first oestrus (Macmillan & Clayton, 1980).

The conclusion from this stidy is that high milk protein percentage was associated with better reproductive performance, especially in early lactation. Cows with higher milk protein percentages during early lactation had higher pregnancy rates to first service.

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