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Cow serum and colostrum immunoglobulin (IgG_1) concentration of five suckler cow breed types and subsequent immune status of their calves

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The objective of this study was to determine the effect of cow breed type on (a) cow serum and colostrum immunoglobulin (IgG_1) concentrations and (b) subsequent calf serum IgG_1 concentration and zinc sulphate turbidity (ZST) units. Five cow breed types were examined: LF (Limousin × Friesian), LLF (Limousin × (Limousin × Friesian)), L (Limousin), C (Charolais) and SLF (Simmental × (Limousin × Friesian)). Three blood samples were taken by jugular venipuncture from the cows at approximately 90, 60 and 30 days pre partum, at parturition and at 15 days or more post partum and from the calves at 48 (40 to 56) h post partum. Prior to suckling a 20 ml sample of colostrum was obtained. Milk yield was estimated using the weigh-suckle-weigh technique. The decrease in serum IgG_1 concentration in cows between 90 days pre partum and parturition was greater ($P < 0.01$) for LF cows than all other breed types, except SLF. There was no difference between LLF, L, C and SLF cows. There was no effect of cow breed type on colostrum IgG_1 concentration. Milk yield was higher ($P < 0.001$) for LF cows than all other breed types, while that of SLF was higher than the three remaining breed types, which were similar. Calf serum IgG_1 concentration and ZST units were higher ($P < 0.01$) for the progeny of LF cows than all others except SLF. There was no difference between the progeny of LLF, L, C and SLF cows. Calf serum IgG_1 was affected by cow breed type and showed a positive relationship with cow serum IgG_1 decreases in late pregnancy.

Keywords: Breed, colostrum, immunoglobulins, suckler cow

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Introduction

The calf is the main saleable product in a suckler enterprise and therefore a key management objective is to ensure that the calf survives and remains healthy. Adequate resistance to infection in the immediate post-parturient period is essential for the health and survival of a calf (Woods and Roussel, 1993). Health problems, especially respiratory disease and diarrhoea are greater in calves with low serum immunoglobulin (Ig) concentrations (McEwan *et al.,* 1970; Fallon, Harte and Harrington, 1986). Immunoglobulins are proteins produced in response to stimulation by antigens (foreign substances) that subsequently inactivate or destroy these antigens. The sera of neonatal calves is essentially devoid of immunoglobulins (Stormont, 1972). Thus calves are entirely dependent on the immunoglobulins received through the ingestion of colostrum to provide passive immunity. The initial secretion present in the mammary gland at or near parturition is termed colostrum (Barrington *et al.,* 2001), which contains immune, growth and tissue repair factors (Uruakpa, Ismond and Akobundu, 2002). Timely ingestion and absorption of colostral immunoglobulins is critical for the survival of ruminant neonates since maternal antibodies are not transported across the placenta, and because their own immune system takes weeks to months to mature and become protective (Boyd, 1972; Banks, 1982). Colostrogenesis, the pre partum transfer of immunoglobulins from maternal circulation into mammary secretions, begins several weeks prior to parturition and ceases abruptly immediately prior to parturition (Brandon, Watson and Lascelles, 1971). IgG_1 is the immunoglobulin isotype found in highest concentration in blood and lacteal secretions of the cow and plays an important role in antibody mediated defence mechanisms (Earley *et al.,* 2000). The Ig concentration of colostrum, in addition to colostrum intake, influences the immune status of the calf. Reports have shown that Ig mass, defined as the volume of colostrum multiplied by the Ig concentration (McGee, 1997), is highly related to calf serum Ig concentration (McEwans *et al.,* 1970; Kruse, 1970b; Bush *et al.,* 1973; Lomba *et al.,* 1978; McGee, 1997) and that Ig mass explains around 50% of the variation in calf serum Ig concentration (Kruse, 1970b; Bush *et al.,* 1973; McGee, 1997). Bush and Staley (1980) concluded that the total Ig mass ingested per unit body weight soon after birth was the most important factor determining serum Ig concentration. Breed effects have been found for cow serum Ig concentration (Williams and Miller 1979; Norman, Hohenboken and Kelley, 1981; Guy *et al.,* 1994; McGee, 1997) and calf serum IgG_1 concentration (Tennant *et al.,* 1969; Kruse, 1970b; Fallon and Harte, 1987; McGee, 1997; Earley *et al.,* 2000). Breed effects have also been found for colostrum Ig concentration (Kruse, 1970a; Lomba, 1978; McGary *et al.,* 1978; Muller and Ellinger, 1981; Norman *et al.*, 1981; Shearer *et al.,* 1992; Guy *et al.,* 1994; Zachwiegja *et al.,* 1997; McGee 1997). The objective of the present study was to determine the effect of breed type on (a) cow serum and colostrum IgG_1 concentrations and (b) the subsequent calf serum IgG_1 concentration and zinc sulphate turbidity (ZST) units.

Materials and Methods

Animals and management

This study was conducted over 2 years using the spring calving suckler herd at Grange Research Centre. The herd comprised 1st and 2nd parity cows in year 1,

while 3rd parity cows were also present in year 2. Five cow breed types were involved: LF (Limousin × Friesian), LLF (Limousin × (Limousin × Friesian)), L (Limousin), C (Charolais) and SLF (Simmental × (Limousin × Friesian)). The mean calving date was 6 April (10 February to 11 June). The cows were housed (slatted-floor shed) in November and offered grass silage *ad libitum* until parturition. They received a daily mineral/vitamin supplement (60 g/head) while housed. The cows that calved prior to April were turned out to pasture in early April. Cows that calved from early April onwards were turned out within 2 to 7 days of calving. Prior to parturition (approximately 1 to 7 days) the cows were moved from the slatted-floor shed to straw-bedded individual calving pens. Immediately post partum tincture of iodine was applied to the umbilical cord of the calf. Colostrum was fed to a small minority of calves, usually following a difficult birth, using a stomach tube.

Sampling

The cows were blood sampled by jugular venipuncture commencing in mid December. Only the earliest calving half of the herd was blood sampled at this time. Samples were subsequently taken at monthly intervals from the whole herd and each cow was sampled at parturition. The blood sample at parturition was usually taken immediately after calving and never more than 24 h post partum. A further sample was taken at about 30 (15+) days post partum. Thus, with the exception of early calving cows, three samples at monthly intervals were collected for each cow prior to calving. In order to present cow serum immunoglobulin concentration at three time-points pre partum, the samples taken from each cow were allocated to the following three categories according to the number of days pre partum; 90 (≥75), 60 (74 to 45) or 30 (44 to 15) days pre partum. Immediately post partum and prior to suckling a 20 ml sample of colostrum was obtained from the right front quarter of the udder, which has been shown to adequately reflect a representative sample from all four quarters (McGee, 1997). If no colostrum was available from the right front quarter, colostrum was taken from the right hindquarter. A blood sample was obtained from the calves at 48 (40 to 56) h post partum. The aim was to supervise all calvings and record precise calving time. However, where calving was not supervised and the calf had already suckled, no colostrum sample was taken. When calving was unsupervised there was still a good indication of calving time due to regular observation and therefore calf blood samples were generally taken.

Milk yield

Milk yield was estimated using the weigh-suckle-weigh technique at lactation day 135 (67 to 199) on average. Two to three estimates per cow were obtained on consecutive days. The calves were restricted to twice-a-day suckling. They were allowed access to the cows in the morning and evening and were weighed before and immediately after suckling to the nearest 0.1 kg. On the morning before the milk yield estimation commenced the calves were separated from their dams and were allowed access to them that evening to ensure that the dams were thoroughly suckled out prior to recording the following morning. Following suckling the calves were "kept moving" to discourage urination or defecation prior to weighing. The separation period was 16.5 h between evening and morning suckling and 7.5 h between morning and evening suckling. Both differences were combined to give a

24-h milk yield estimate. Milk yield data for any cow that was not fully suckled out was excluded from the results, as was yield data when the calf urinated or defecated prior to weighing post suckling.

Immunological measurements

The concentration of IgG_1 in serum and colostrum were measured quantitatively by single radial immunodiffusion procedures (Mancini, Carbonara and Heremans, 1965) by reference to an internal IgG_1 standard (Bovine IgG_1 VET–RID Kits, Bethyl Laboratories Inc., Montgomery, USA). The zinc sulphate turbidity (ZST) test was performed on calf serum samples at 20 °C, with the turbidity measured at 520 nm using a spectrophotometer (McEwan *et al.,* 1970).

Statistical analysis

The data structure is presented in Table 1 where the number of records collected and the number of individual cows with records are presented for each variable. Analysis of variance was carried out as a repeated measures analysis using the PROC MIXED of SAS (SAS Institute, Inc., 1999). The fixed effects in the model used to analyse cow serum IgG_1 concentration over time (Model 1), were dam breed, parity, year and sample time. The interaction terms included were dam breed by sample time and parity by sample time. The fixed effects in the model used to analyse colostrum IgG_1 concentration, calf serum IgG_1 concentration units 48 h after birth, calf serum ZST units 48 h after birth and milk yield (Model 2), were dam breed, parity and year. No interaction terms were included in the final model for these variables as $P > 0.1$ in all cases. In the model used to analyse weekly change pre partum in cow serum IgG_1 concentration (Model 3), a

Table 1. Number of records collected for each variable

Variable	Cow breed type[1]				
	LF	LLF	L	C	SLF
IgG_1 in cow serum					
Day 90 pre partum	26 (21)[2]	36 (24)	24 (20)	21 (13)	28 (19)
Day 60 pre partum	41 (26)	36 (25)	31 (23)	32 (19)	46 (29)
Day 30 pre partum	37 (23)	34 (23)	26 (20)	30 (20)	39 (28)
Parturition	46 (26)	47 (29)	30 (23)	33 (21)	47 (29)
Day 30 post partum	46 (26)	39 (24)	28 (21)	33 (20)	48 (29)
Weekly change in serum IgG_1 pre partum	44 (26)	45 (28)	30 (23)	33 (19)	42 (29)
IgG_1 in colostrum	38 (22)	29 (21)	19 (17)	31 (20)	39 (28)
Milk yield	29 (21)	30 (20)	27 (18)	24 (19)	33 (25)
Calf serum at 48 h post partum					
IgG_1	43 (24)	40 (26)	27 (19)	30 (20)	42 (26)
ZST	43 (24)	41 (27)	27 (19)	30 (20)	42 (26)

[1] LF = Limousin × Friesian, LLF = Limousin × (Limousin × Friesian), SLF = Simmental × (Limousin × Friesian), L = Limousin, C = Charolais.
[2] Number of individual cows.

parity by year interaction term was included. Individual cow within dam breed was included as a random variable and calving day was included as a covariate in all models. Least squares means for dam breed by sample time were used for cow serum IgG_1 concentration and dam breed for all other variables. The Tukey-Kramer multiple range test within SAS was used to evaluate differences among the least squares means. The linear regression of cow serum IgG_1 concentration (Y) on the number of days pre partum when the sample was taken (X) was calculated, using PROC REG (SAS, 1999), to estimate the daily change pre partum in cow serum IgG_1 concentration for each animal (multiplied by 7 for weekly). Simple correlations were calculated using PROC CORR (SAS, 1999). The variables were not adjusted for the effects in the model prior to computing correlation coefficients.

Results

Cow serum and colostrum IgG_1 concentration

There was a significant cow breed type by sample time interaction ($P < 0.01$) for

Table 2. Least squares means for effect of cow serum on IgG_1 concentrations and changes, colostrum IgG_1 concentration, milk yield and calf serum IgG_1 concentration and ZST units at 48 h post partum

Variable	Cow breed type[1]					s.e.[2]	F-test[3]
	LF	LLF	L	C	SLF		
IgG_1 in cow serum at (mg/ml)[4]							
Day 90 pre partum	11.9	11.2	12.6	12.6	11.4	0.69	
Day 60 pre partum	10.7	9.8	11.3	11.8	11.4	0.62	
Day 30 pre partum	9.3	8.5	10.5	11.5	9.6	0.68	
Parturition	5.3[a]	7.6[ab]	8.8[b]	9.3[b]	6.9[a]	0.61	**
Day 30 post partum	10.1	10.5	11.6	12.4	10.9	0.62	
Weekly change in IgG_1 concentration in cow serum (mg ml^{-1} $week^{-1}$)	–0.54[b]	–0.40[a]	–0.35[a]	–0.28[a]	–0.45[ab]	0.064	**
IgG_1 in colostrum (mg/ml)	79.7	76.4	75.7	95.5	89.3	7.87	
Milk yield[4] (kg/day)	9.1[c]	6.6[a]	5.1[a]	5.5[a]	8.0[b]	0.41	***
Immunoglobulins in calf serum at 48 h post partum							
IgG_1 (mg/ml)	27.1[b]	21.6[a]	20.6[a]	18.1[a]	24.2[ab]	2.15	**
ZST (units)	17.9[b]	14.0[a]	14.6[a]	12.6[a]	14.7[ab]	1.08	**

[1] LF = Limousin × Friesian, LLF = Limousin × (Limousin × Friesian), SLF = Simmental × (Limousin × Friesian), L = Limousin, C = Charolais.
[2] Maximum standard error.
[3] Significant cow breed type by sample time interaction ($P < 0.01$), reflecting the fact that there was no significant breed type effect on serum IgG_1 concentration at any time point pre partum or at 30 days post partum, however at parturition the breed type effect was significant.
[4] At about day 135 post partum.
[abc] Within rows, means without a different superscript differ significantly.

cow serum IgG_1 concentration. This reflected the finding that there was no significant effect of cow breed type on serum IgG_1 concentration at any time point pre partum or at 30 days post partum, however at parturition the effect of cow breed type was significant (Table 2). At parturition serum IgG_1 concentration of C and L cows were similar and significantly higher than that of LF and SLF cows, while that of LLF cows were intermediate. Serum IgG_1 concentration of LF and SLF were not significantly different. There was a significant effect of cow breed type on the weekly decrease in pre partum serum IgG_1 ($P < 0.01$). The weekly decrease was largest for LF cows, and significantly greater than that of all other breed types except the SLF cows. The weekly pre-partum decrease in serum IgG_1 for SLF, LLF, L and C cows were similar. Serum IgG_1 concentration had increased at 30 days post partum and there was no significant difference between the breed types. There was no significant effect of cow breed type on colostrum IgG_1 concentration.

Milk yield

Milk yield (Table 2) was significantly higher ($P < 0.001$) for LF cows than all other breed types, while that of SLF cows was significantly higher than the three remaining breed types. There was no significant difference in milk yield between LLF, C and L cows.

Calf serum IgG_1 concentration and ZST units

There was a significant effect of cow breed type on calf serum IgG_1 concentration ($P < 0.01$) and on ZST units ($P < 0.01$) 48 h after birth (Table 2). The progeny of LF cows had higher serum IgG_1 concentration and ZST units than that of all other breed types except SLF. These two measurements of calf immune status were similar for the progeny of SLF, LLF, L and C cows.

Correlations between cow and calf parameters

The correlation coefficients (Table 3) between colostrum IgG_1 concentration and calf serum IgG_1 concentration, ZST units at 48 h post partum and milk yield were low and not significant.

The correlation coefficients between measurements of calf serum immunoglobulin (IgG_1 concentration and serum ZST units) and cow serum IgG_1 at 90 days pre partum or at parturition were

Table 3. Correlations involving IgG_1 concentrations in cows, milk yield and immunoglobulin status of calves at 48 h post partum

Cow variable	Immunoglobulins in calf serum at 48 h		Milk yield at day 135 of lactation
	IgG_1 (mg/ml)	ZST (units)	
IgG_1 concentration in serum at			
Day 90 pre partum	0.06	0.06	–0.08
Parturition	–0.15	–0.15	–0.44***
Weekly change in serum IgG_1 concentration during the pre partum period	0.07	0.02	0.21*
IgG_1 concentration in colostrum	0.09	–0.08	–0.15
Milk yield at day 135 of lactation	0.34***	0.35***	

low and not significant. The correlation between milk yield and cow serum IgG_1 90 days pre partum was not significant. There was a highly significant ($P < 0.001$), negative correlation between milk yield and cow serum IgG_1 at parturition. The correlation coefficients between weekly change in cow serum IgG_1 concentration pre partum and either calf serum IgG_1 concentration or ZST units 48 h after birth were low and not significant. The correlation coefficients between milk yield and cow serum IgG_1 weekly change and between calf serum IgG_1 concentration and calf serum ZST units were positive and significant. The correlation between calf serum IgG_1 concentration and serum ZST units 48 h was 0.71 ($P < 0.001$).

Discussion

Cow serum and colostrum IgG_1 concentration

The non-significant differences among the breed types for serum IgG_1 concentration at 90 and 60 days pre partum agree with the findings of Guy *et al.* (1994) and McGee (1997), who found no significant difference between breed types prior to day 45 pre partum. In the present study breed type effects had not emerged even at 30 days pre partum. Guy *et al.* (1994) reported lower IgG_1 concentrations between days 28 and 24 pre partum in dairy cows compared to beef cows. The significant effect of cow breed type both on serum IgG_1 at parturition and on the decrease over the period from 90 days to pre partum is associated with the transport of immunoglobulins from the blood stream across the mammary barrier and into the lacteal secretion during colostrogenesis. Similar breed differences have previously been reported (Brandon *et al.* 1971; Williams and Miller, 1979; Guy *et al.,* 1994; McGee, 1997; Barrington *et al.,* 2001). The greater decrease in cow serum IgG_1 concentration between 90 days pre partum and parturition for LF cows suggests that more IgG_1 was transferred into the mammary secretion in LF cows. Cows with a higher colostrum yield (dairy cross) will produce a greater Ig mass, assuming similar colostrum Ig concentrations. McGee (1997) reported higher colostrum yield in cow breed types with higher milk yield, in all comparisons of beef × Friesian (BF) with Charolais (C) cows. Therefore, it was assumed in this study, that colostrum yield was greater for LF cows, given the higher milk yield compared to the other breed types, thus resulting in higher Ig mass. Guy *et al.* (1994) and McGee (1997) found a larger decrease in IgG_1 pre partum in dairy cross cows than beef cows associated with increased colostral Ig mass production. McGee (1997) reported increased cow serum IgG_1 concentration post partum as found in the present study.

McGee (1997) found no cow breed type effects for colostral IgG_1 or IgA, but IgG_2 and IgM were significantly lower for C cows than for BF cows. McGary *et al.* (1978) reported that purebred Charolais cows had lower colostrum Ig concentrations than C × Brown Swiss cows. Zachwiegja *et al.* (1997), working with C × Red White cows of 0%, 50% and 75% C genes, reported that cows with a high proportion of C genes had significantly lower colostrum Ig concentrations than those with a lower proportion of C genes. Breed type differences may be present for one immunoglobulin subclass but not another (Norman *et al.,* 1981). Breed type differences in colostral Ig concentration have been reported in other studies (Kruse, 1970a; McGary *et al.,* 1978; Muller

and Ellinger, 1981; Norman *et al.,* 1981; Shearer *et al.,* 1992; Zachwiegja *et al.,* 1997). Prichett *et al*. (1991) and McGee (1997) reported a negative relationship between colostrum IgG_1 concentration and milk yield, which agrees with the present study. However the colostral IgG_1 concentrations reported here (beef cows) are higher than those reported for dairy cows (Guy *et al.,* 1994; Morin, McCoy and Hurley, 1997). Kruse (1970b) and Morin *et al.* (1997) reported that colostrum yield and Ig concentration are inversely related at very high yields. The significant positive correlation coefficient between milk yield and calf immune status and the non-significant correlation of the latter with colostrum IgG_1 concentration in this study, suggest that the volume of colostrum produced is the more important determinant of calf immune status.

Calf serum IgG_1 concentration and ZST units

The higher calf serum IgG_1 concentration and ZST units 48 h after birth for the progeny of LF and SLF cows, was presumably due to the higher Ig mass that they consumed. Milk production potential should therefore be such that it will ensure adequate colostrum intake by the calf. This is of particular relevance to first parity cows, as their milk yield is lower than for mature cows. The calf serum IgG_1 concentrations reported here are higher than those reported for dairy calves by Morin *et al.* (1997). Findings by Earley *et al.* (2000) imply that, compared to suckled calves, dairy calves do not receive either adequate quantity or quality of colostrum soon enough after birth. A stronger positive relationship would have been expected between the weekly changes in pre partum cow serum IgG_1 concentration and calf immune variables and milk yield. A greater decrease in pre partum cow serum IgG_1 is associated with greater Ig mass production (Guy *et al.,* 1994). The stronger positive correlation between milk yield, assumed to reflect colostrum yield, and calf immune status variables is possibly due to a resultant increase in the mass of Ig consumed. The significant correlation between IgG_1 and ZST, in agreement with McGee (1997), shows that the ZST test is a good indicator of calf immune status and has the additional advantages of taking less time to assess and being cheaper.

Conclusions

The cow breed type effects on serum IgG_1 concentration at parturition are a result of differences in the quantity of immunoglobulins transferred from the blood stream to the lacteal secretion during colostrogenesis. The significant cow breed type effects on calf immunoglobulin status were due to differences in colostrum volume produced and therefore immunoglobulin mass consumed by the calf.

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