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Effect of suckler cow genotype on cow serum immunoglobulin (Ig) levels, colostrum yield, composition and Ig concentration and subsequent immune status of their progeny

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Survival of the neonatal calf is largely dependent on humoral immunity. The objective of three experiments reported here was to compare cow serum immunoglobulin (Ig) concentration, colostrum yield, composition and Ig concentration and calf serum Ig concentrations at ~8- and 48-h post partum of spring-calving Charolais (C) and Beef × Holstein-Friesian (BF) cows and their progeny. Cows were individually offered a restricted allowance of grass silage pre partum in Experiments 1 and 2 and silage *ad libitum* in Experiment 3. In Experiment 1 calves were assisted to suckle after parturition. In Experiments 2 and 3, colostrum yield and Ig concentration were measured following administration of oxytocin and hand milking of half or the complete udder, respectively. It was intended to feed each calf 50 ml (Experiment 2) or 40 ml (Experiment 3) of colostrum per 1 kg birth weight via stomach tube. Following an 8-h period, during which suckling was prevented, a further colostrum sample was obtained. The decrease in cow serum IgG_1 concentration pre partum was greater ($P < 0.05$) in BF cows than C cows. In comparison to BF cows, C cows had a lower colostrum yield ($P < 0.001$) and the colostrum had lower concentrations of dry matter ($P < 0.01$), crude protein ($P < 0.05$), fat ($P < 0.05$), IgG_1 ($P = 0.06$), IgG_2 ($P < 0.01$), IgM ($P < 0.01$) and Ig total ($P < 0.05$). The mass of IgG_1, IgG_2, IgM, IgA and Ig total in the colostrum produced was significantly lower for C cows than BF cows. Calves from C cows had significantly lower serum Ig subclass concentration at 48-h post partum than calves from BF cows. In conclusion, due to a lower Ig mass produced by their dams, calves from C cows had a lower humoral immune status than those from BF cows.

Keywords: Colostrum; genotype; immunoglobulins; suckler cows

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Introduction

Due to the increased proportion of suckler cows in the national herd, the replacement of Friesians by Holsteins in the dairy herd (undesirable from a beef point of view) and a preference for home-bred animals, to reduce costs and avoid introducing disease, the retention of replacements from within the suckler herd has increased in Ireland. Such a breeding policy will inevitably result in an increasing proportion of Charolais breed in the suckler cow herd as it is the most widely used sire breed.

Suckler cow enterprises depend on the production of a healthy calf. Lack of neonatal disease resistance in the immediate post-parturient period is a significant cause of reduced livestock productivity and consequent economic loss. Greene and Bakheit (1980) reported that over 11% of calves die each year (abortion 2%, stillbirths 6% and neonatal death 3.2%) while results of a survey of over 2400 Irish farms (Mannion, Phelan and Crilly, 1987) showed that of all the calves born annually 6.7% died (two thirds at calving) and approximately 14% required drugs or veterinary treatment. Diarrhoea or septicaemia accounted for over half of all deaths in very young calves (Greene and Bakheit, 1980; Mannion *et al.,* 1987).

The importance of passive or humoral immunity, through absorption of colostral antibodies or immunoglobulins (Ig), to the survival and health of a newborn calf is well recognised (Roy, 1990). Each of the major Ig subclasses, namely, immunoglobulin G (IgG_1 and IgG_2), immunoglobulin M (IgM) and immunoglobulin A (IgA) have a specific role to play in protecting the calf against disease or infection (Earley *et al.,* 2000). Ensuring that calves receive adequate passive immunity via colostrum ingestion could reduce these diseases, resulting treatments and deaths.

In comparison to the dairy calf or bucket-rearing systems there is a deficit of information in the scientific literature on suckler dam serum Ig concentration, colostrum yield, chemical composition and Ig concentration, and subsequent calf serum Ig status. Indeed the literature is almost devoid of studies that have examined all aspects in one experiment. There appear to be no studies in the literature comparing the genotypes used in the present study. Presently, colostrum management for the suckler calf has to use modified dairy calf guidelines.

The objective of the three experiments reported here was to determine the effect of cow genotype on cow serum Ig subclass levels, colostrum yield, composition and Ig concentration, and the subsequent humoral immune status of their calves.

Materials and Methods

Animals, feeding and general management

Data were obtained in three consecutive years (experiments) comparing spring calving (commencing mid-February) upgraded (≥ 7/8) Charolais (C) cows with first cross Beef (Hereford and Limousin) × Holstein-Friesian (BF) cows. Each year the cows were bred using two Charolais sires (across breeds). All cows were accommodated in tie-up stalls and were individually offered restricted (approximately 30 kg fresh weight daily) grass silage (*in vitro* dry matter digestibility (DMD) 637 and 639 g/kg in Experiments 1 and 2, respectively) pre partum in the first two experiments and grass silage *ad libitum* (*in vitro* DMD 686 g/kg) pre partum in the third experiment. In addition, all cows received a suitable mineral and vitamin supplement daily. All cows were given a combined bovine rotavirus and *E. coli* vaccine (inactivate) (*Rotavec K99,* Mallinckrodt) by intramuscular

injection between 4 and 12 weeks prior to expected calving date.

Cows were removed from the tie-up stalls prior to parturition (generally 1 to 4 days) and placed in straw-bedded calving pens. Calves received tincture of iodine to the umbilical cord immediately post partum. After parturition cows remained in the pens with the calf having free access (after experimental protocol was implemented) to the dam. The animals used in each experiment were the early-calving cows and their calves from a larger herd.

In Experiment 1, any calf not suckling within 1 h of birth was assisted to suckle and subsequently left with the dam. In the subsequent two experiments all births were supervised to ensure that calves did not suckle the cow prior to implementing the experimental protocol.

Colostrum yield, sampling and feeding

In Experiments 2 and 3, the calf was weighed immediately following parturition, and the cow was put into a restraining pen and the calf placed at her head to allow grooming. The cow received 40 i.u. of oxytocin (*Oxytocin Leo*) intramuscularly to facilitate milking to assess colostrum yield. In Experiment 2 one half of the udder was hand milked to completion. Each front and rear quarter was milked out separately the volume was recorded and combined and then multiplied by two to estimate total yield. Three 20 ml samples were retained for analyses. The objective was to feed each calf 50 ml of colostrum per 1 kg birth weight. If the udder half did not yield sufficient colostrum the other quarters were milked out as required and a further 20 ml sample taken. All calves were then fed colostrum using an oesophageal feeder and bag (stomach tube) within 1 h of birth. After feeding, a muzzle was placed on the calf to prevent suckling and the calf was left in the presence of the dam to avoid any adverse effect of separation on Ig absorption (Fallon, Harte and Keane, 1989). At 8 h post-feeding, a further colostrum sample was obtained (without oxytocin) from the previously milked half by hand milking approximately 100 ml from the front and back quarters and compositing it. The calf was then assisted to suckle and left with free access to the cow. In Experiment 3 the procedure was as described in Experiment 2 except that the entire udder was hand milked to completion. The objective was to feed each calf 40 ml of colostrum per 1 kg birth weight and colostrum in excess of the calf's allowance (if any) was stored at approximately 30 °C. At 8 h post-feeding a further colostrum sample (without oxytocin) was obtained by hand milking out approximately 70 ml from each quarter and compositing it. The calf was then fed the excess colostrum, if any (0 to 5350 ml), from the first milking using a stomach tube and assisted to suckle if interested. Subsequently, the calf was allowed free access to the cow. Some calves experienced discomfort coping with relatively large volumes (circa 4.0 l) at the second feeding and two started to regurgitate colostrum. When any discomfort was detected, the stomach tube was withdrawn and the remaining volume was fed 8 h later. All colostrum samples were stored at approximately –20 °C prior to analyses for Ig and chemical composition.

Blood sampling

In Experiments 2 and 3 cows were blood sampled by jugular venipuncture prior to morning feeding every 2 weeks during the indoor winter feeding period using a 10 ml vacutainer. A blood sample was similarly obtained from calves at 8 h post feeding in Experiments 2 and 3 and at 48 h post partum in all three experiments. As precolostral calf serum is normally devoid of

Ig (Halliday *et al.,* 1978; Field *et al.,* 1989) it was deemed unnecessary to blood sample the calf at birth. Although there is general consensus in the literature that Ig absorption closure in the calf occurs around 24 h post partum some studies have suggested later closure for individual subclasses (e.g. Langholz *et al.,* 1987). Consequently, blood samples were collected at 48 h post partum. Blood samples were allowed to clot at room temperature for 1 h followed by a 24 h period at 4 °C prior to centrifuging at 1600 g for 20 minutes. Serum samples were stored at approximately –20 °C prior to analysis for Ig.

Data were obtained from the progeny of 16 C and 25 BF cows in Experiment 1 and from 14 C and 24 BF cows and their progeny in both Experiments 2 and 3.

Immunoglobulin absorption

Efficiency of absorption at 8 h post feeding was calculated in Experiments 2 and 3 for each Ig subclass by using the Ig concentration in the colostrum and the Ig concentration in serum to determine the circulating Ig mass in the calf divided by the Ig mass consumed by the calf. Mass of Ig in the calf was calculated by multiplying the concentration of serum Ig by the plasma volume. Plasma volume was presumed to be 7% of calf birth weight (Vann *et al.*, 1995). Quantity of Ig fed was calculated from the volume fed × Ig concentration in the colostrum.

Chemical analyses

Crude protein (CP) in colostrum was determined by Kjeldahl (N × 6.38), crude ash by muffle furnace at 550 °C, fat by acid hydrolysis and lactose by the method of Birch and Mwangelwa (1974). Colostrum and serum IgG_1, IgG_2, IgM and IgA concentrations were determined using the single Radial Immuno-Diffusion (s.R.I.D.) test derived from the work of Mancini, Carbonara and Heremans (1965) and Fahey and McKelvey (1965), carried out on agar plate kits and calculated via an internal Ig standard [*BINDARID, NANORID* kits, The Binding Site Ltd., Birmingham, England]. Ig total was the sum of the four Ig subclasses. Ig concentrations in colostrum were determined on a fat-free sample obtained by centrifugation. The zinc sulphate turbidity (ZST) test was performed on calf serum samples at 20 °C (McEwan *et al*., 1970) with turbidity measured at 520 nm using a spectrophotometer.

Statistical analysis

Data for Experiment 1 were subjected to analysis of variance using PROC GLM of SAS (2001). The model had terms for cow genotype, calf sex and sire. Data for Experiments 2 and 3 were combined and analysed using PROC MIXED of SAS (2001) with repeated measures. The model for cow data had terms for genotype, experiment and their interaction, while the model for calf data also included terms for sire and calf sex. All models had cow lactation number and calving day included as covariates. Least-squares means are reported with standard errors.

Results

Ig in cow serum

The serum concentration of IgG_1, IgG_2, IgM and IgA during the pre- and post-partum periods are summarised in Figure 1. IgG_1 concentrations were higher ($P < 0.001$) for C cows than BF cows. The decrease in IgG_1 pre partum and increase in IgG_1 post partum were greater ($P < 0.05$) for BF cows than C cows. Cow IgG_2 concentration increased ($P < 0.001$) pre partum and, subsequently, post partum ($P = 0.06$) but there was no evidence of any genotype differences. There was a genotype × time interaction ($P < 0.01$) for IgM

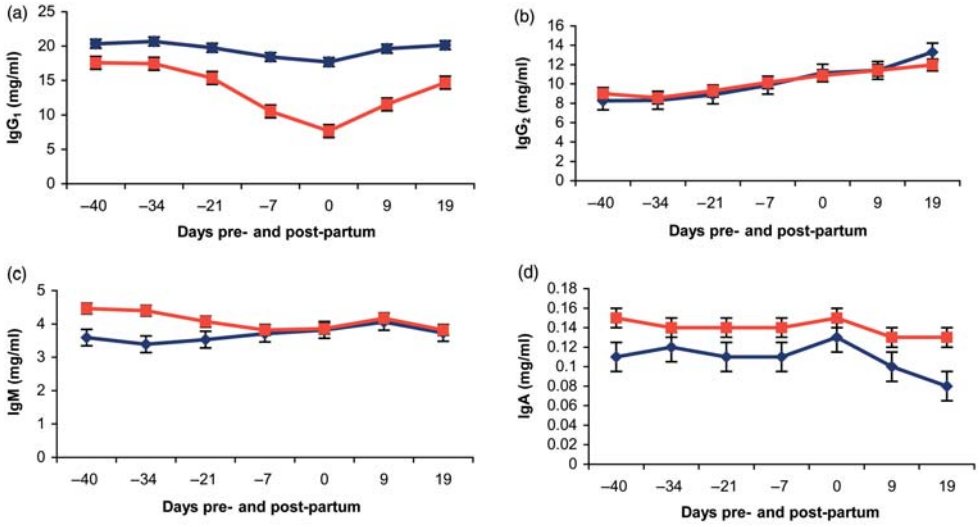

Figure 1: Least squares means for immunoglobulin concentrations in serum from Charolais (◆) and Beef × Holstein-Friesian (■) cows during the pre- and post-partum period: (a) IgG_1, (b) IgG_2, (c) IgM and (d) IgA.

reflecting the fact that concentration increased pre partum in C cows but decreased in BF cows. IgA concentration was lower ($P < 0.05$) in C cows than BF cows.

Colostrum composition, yield, Ig concentration, Ig mass and colostrum feeding

Colostrum yield, composition and Ig subclass concentrations at first milking are presented in Table 1. Colostrum yield was lower ($P < 0.001$) for C cows than BF cows. The colostrum from C cows had lower concentrations of DM ($P < 0.01$), CP ($P < 0.05$) and fat ($P < 0.05$) than BF cows but there was no effect of genotype on the concentrations of ash or lactose. Compared to BF cows C cows had a lower concentration of IgG_1 ($P = 0.06$), IgG_2 ($P < 0.01$), IgM ($P < 0.01$), IgA ($P = 0.08$) and Ig total ($P < 0.05$) in the first-milking colostrum. Concentrations of IgG_2 and IgM were lower ($P < 0.05$) in the colostrum obtained at second milking for C cows than BF cows but differences were not significant between the genotypes for IgG_1, IgA or Ig total. In both genotypes, colostrum Ig concentrations at second milking were lower ($P < 0.001$) than at first milking. BF cows produced a significantly greater mass of IgG_1, IgG_2, IgM, IgA and Ig total than C cows at first milking (Table 1). The volume of colostrum fed at birth was significantly higher for the progeny of BF cows than C cows both on an absolute basis and when scaled for weight. In Experiment 3, the volume of colostrum fed at 8 h post-feeding was also greater ($P < 0.001$) for the progeny of the BF cows.

Calf serum Ig concentration and Ig absorption efficiency

In Experiment 1, under a natural suckling situation, calves from BF cows had significantly higher concentrations of

Table 1. Least squares means (s.e.) for effect of cow genotype on colostrum yield, composition and immunoglobulin concentration, and on calf birth weight and volume of colostrum fed (Experiments 2 and 3 combined)

Item	Genotype		Significance
	Charolais	Beef × Friesian	
No. of animals	28	48	
Colostrum yield (ml)	2559 (308.7)	3919 (201.2)	***
Composition of colostrum at first milking			
Dry matter (DM) (g/kg)	245 (7.9)	272 (4.9)	**
Crude protein (g/kg DM)	150 (6.4)	169 (4.0)	*
Ash (g/kg DM)	11 (2.3)	13 (1.4)	
Fat (g/kg DM)	48 (3.6)	58 (2.3)	*
Lactose (g/l)	29 (1.4)	26 (0.9)	
Ig concentration (mg/ml) in colostrum at first milking			
IgG_1	153.2 (10.87)	178.1 (7.02)	
IgG_2	2.1 (0.38)	3.5 (0.24)	**
IgM	7.9 (0.82)	10.9 (0.52)	**
IgA	2.5 (0.34)	3.3 (0.21)	
Ig total	165.7 (11.50)	195.7 (7.41)	*
Ig concentration (mg/ml) in colostrum at second milking			
IgG_1	73.1 (8.62)	88.6 (5.48)	
IgG_2	1.1 (0.24)	1.8 (0.15)	*
IgM	3.6 (0.55)	5.1 (0.35)	*
IgA	1.2 (0.17)	1.5 (0.12)	
Ig total	79.0 (9.30)	97.0 (5.93)	
Ig mass (g) – yield at first milking			
IgG_1	384.9 (57.2)	665.8 (36.5)	***
IgG_2	5.2 (1.45)	13.3 (0.92)	***
IgM	19.9 (4.60)	43.6 (2.93)	***
IgA	6.7 (1.49)	12.2 (0.94)	**
Ig total	416.8 (62.43)	734.8 (39.86)	***
Calf birth weight (kg)	47.9 (1.24)	45.9 (0.83)	
Colostrum fed at birth			*
Absolute (ml)	1713 (88.8)	1989 (57.7)	
Relative to birth weight (ml/kg)	36.6 (1.60)	43.4 (1.02)	***
Colostrum fed at 8 h post partum[1]			
Absolute (ml)	776 (364.0)	2570 (276.9)	***
Relative to birth weight (ml/kg)	18.1 (8.18)	56.6 (6.23)	***

[1] Experiment 3 only.

IgG_1, IgG_2, IgM, Ig total and higher ZST units at 48 h post partum than calves from C cows (Table 2).

For Experiments 2 and 3 combined, calves from BF cows had significantly higher serum IgG_2, IgM and IgA concentrations

Table 2. Least squares means (s.e.) for effects of cow genotype on immunoglobulin (Ig) concentration in calf serum at 8 and 48 h post partum and on immunoglobulin absorption efficiency for Experiment 1 and combined data for Experiments 2 and 3

	Experiment						
	1			2 and 3			
	Genotype		Significance	Genotype		Significance	
Item	Charolais	Beef × Friesian		Charolais	Beef × Friesian	G	G × E[1]
No. of animals	16	25		24	48		
Ig concentration (mg/ml) at 8 h post partum							
IgG_1	–	–	–	34.8 (2.64)	45.9 (1.74)	***	*
IgG_2	–	–	–	0.5 (0.09)	0.9 (0.06)	***	
IgM	–	–	–	2.5 (0.24)	3.4 (0.15)	**	
IgA	–	–	–	0.7 (0.09)	0.9 (0.06)	*	
Ig total	–	–	–	38.5 (2.84)	51.2 (1.89)	***	*
ZST units[2]	–	–	–	13.6 (0.98)	18.8 (0.64)	***	
Ig concentrations at 48 h post partum							
IgG_1	48.2 (4.61)	62.4 (3.67)	*	36.2 (3.49)	54.6 (2.15)	***	
IgG_2	0.6 (0.09)	1.2 (0.07)	***	0.5 (0.12)	1.14 (0.07)	***	
IgM	2.8 (0.28)	4.3 (0.23)	***	2.6 (0.31)	4.0 (0.19)	***	
IgA	0.6 (0.08)	0.8 (0.06)		0.5 (0.11)	0.9 (0.07)	***	
Ig total	52.2 (4.83)	68.5 (3.85)	*	39.8 (3.73)	60.7 (2.30)	***	
ZST units[2]	19.9 (1.70)	26.7 (1.35)	**	17.9 (1.47)	24.5 (0.93)	***	
Ig absorption efficiency							
IgG_1	–	–	–	0.43 (0.023)	0.43 (0.015)		*
IgG_2	–	–	–	0.46 (0.026)	0.42 (0.020)		
IgM	–	–	–	0.64 (0.026)	0.54 (0.021)	**	
IgA	–	–	–	0.53 (0.024)	0.46 (0.019)	*	
Ig total	–	–	–	0.44 (0.022)	0.44 (0.014)		*

[1] Genotype × Experiment interaction.
[2] ZST = Zinc Sulphate turbidity test.

at 8 h post-feeding than calves from C cows. There was a genotype × experiment interaction for IgG_1 and Ig total ($P < 0.05$) concentrations and ZST levels ($P = 0.06$) at 8 h post-feeding reflecting the significantly lower Ig concentrations for calves from C cows compared with calves from BF cows in Experiment 2 (IgG_1, 32.1 v. 52.6 mg/ml; Ig total, 35.4 v. 58.2 mg/ml; ZST units, 17.4 v. 25.2) but not in Experiment 3 (IgG_1, 37.4 v. 39.2 mg/ml; Ig total, 41.5 v. 44.3 mg/ml; ZST units, 9.9 v. 12.4). At 48 h post partum the concentrations of IgG_1, IgG_2, IgM, IgA and Ig total and ZST levels were all significantly higher in calves from BF cows than C cows.

The difference between serum Ig concentrations at 8 h and 48 h was greater for calves from BF cows than those from C cows for IgG_1 ($P = 0.06$), IgG_2 ($P < 0.01$), IgM ($P < 0.05$) and Ig total ($P < 0.05$). Compared to calves from BF cows, calves from C cows had a higher absorption efficiency for IgM ($P < 0.001$) and IgA ($P < 0.05$). There was a genotype × experiment interaction ($P < 0.01$) due to the greater absorption efficiency of IgG_1 and Ig total for calves from BF cows than C cows in Experiment 1 while the reverse occurred in Experiment 2. There was no effect of genotype on absorption efficiency of IgG_2.

Discussion

The lower IgG_1 levels in the serum of BF cows compared with C cows is consistent with the findings of Guy *et al.* (1994) who found lower IgG_1 levels in Holstein than beef (Charolais and Hereford cross) cows. The decrease in serum IgG_1 levels in cows pre partum in association with colostrogenesis has been previously reported (Olson *et al.*, 1981a; McCutheon *et al.*, 1991; Guy *et al.*, 1994). The greater decrease in cow serum IgG_1 concentrations in BF cows than C cows suggests that more IgG_1 was transferred into the mammary secretion. This was confirmed by the significantly greater colostral Ig mass produced by these cows. Similarly, Guy *et al.* (1994) found that the decline of serum IgG_1 in beef cows was slight but significant while in dairy cows the decline was dramatic and was associated with a larger colostral Ig mass. The increase in IgG_2 concentrations in cow serum pre partum in both genotypes agrees with previous reports (Olson *et al.*, 1981a; McCutheon *et al.*, 1991).

The objective of feeding the calf a colostrum volume at a fixed proportion of birth weight to attain the equivalent colostrum intake for both genotypes was not realised in either experiment. It was intended to feed each calf 50 ml (Experiment 2) or 40 ml (Experiment 3) of colostrum per kg birth weight. The initial value of 50 ml/kg was decided on following a review of the literature on colostrum yields from suckler cows (McGee, 1997). Although recommendations for dairy calves often suggest feeding up to about 4.0 l of colostrum immediately post partum, indications were that the colostrum yield in suckler cows is generally significantly lower than this (McGee, 1997), which was confirmed in the present study. As the target value of 50 ml/kg was not attained in Experiment 2 it was reduced to 40 ml/kg in Experiment 3. The reduction of 10 ml/kg was deemed to be sufficient considering the relative colostrum yield achieved in Experiment 2 (39.7 and 46.9 ml/kg birth weight for C and BF cows, respectively) and the fact that cows were offered a restricted silage diet compared to an *ad libitium* silage diet in Experiment 3. Nutritional restriction of the dam has been shown to adversely affect colostrum yield (Logan, 1977).

Literature reports have shown significant breed differences in colostrum yield (Kruse, 1970; Petrie, Acres and McCartney, 1984;

Vann *et al.*, 1995). The lower colostrum yield of C cows is consistent with reports on breed differences in milk yield, whereby the introduction of dairy breeding increases the milk yield of beef breeds and generally beef × dairy breeds have a higher milk yield than beef breeds (McGee, 1997). The large variation found in colostrum yield (ranging from 740 to 5490 ml for CH and 1660 to 7230 ml for BF cows) between cows in the present study agrees with previous reports in both beef (Logan, 1977; Petrie *et al.*, 1984; Field *et al.*, 1989) and dairy (Devery-Pocius and Larson, 1983) cows.

The colostrum Ig concentrations obtained in this study, especially IgG_1, are at the upper end of reported values using the s.R.I.D. technique but are comparable with values obtained by Delong *et al.* (1979), Langholz *et al.* (1987) and Shell *et al.* (1995). In agreement with previous studies (Logan, Meneely and Lindsay, 1981; Fallon *et al.*, 1989) there was a large variation in colostrum Ig concentration between cows at first milking.

Dairy cows have lower colostrum Ig concentration than beef cows (Guy *et al.,* 1994). Thus, beef-breed by dairy-breed crossbreds would be expected to produce colostrum with an Ig concentration which is intermediate. This was not the case in the present study suggesting that the C breed may have lower colostrum Ig concentration than other beef breeds, such as the Limousin or Hereford. McGary *et al*. (1978) (cited by Norman, Hohenboken and Kelley, 1981) reported that purebred Charolais cows had lower colostrum Ig concentrations than Charolais × Brown Swiss cows. Similarly, Zachwiegja *et al.* (1997) reported that Charolais × Red White breed cows (0, 0.5 and 0.75 Charolais) with a high proportion of Charolais genes had significantly lower colostrum Ig concentration than those with a low proportion of Charolais genes. The importance of first milking colostrum was demonstrated. The approximate halving of Ig concentration in second milking colostrum agrees with previous results in both dairy (Stott, Fleenor and Kleese, 1981; Fallon *et al.*, 1989) and beef (Logan, 1977; Vann *et al.*, 1995) cows.

The absolute values for Ig total in calf serum obtained with the s.R.I.D. method are at the upper end of literature reports but are comparable with some studies on beef calves (Delong *et al.,* 1979; Olson *et al.,* 1981b; Bradley and Niilo, 1984; Langholz *et al.,* 1987). Reasons proposed for the high calf serum Ig levels found in the present experiments are the high Ig concentration in the colostrum and the fact that all calves suckled or were fed within 1 h of birth.

The greater difference between the 8- and 48-h calf serum Ig concentration in BF progeny compared to C progeny is not surprising considering the difference in colostrum Ig mass produced by the genotypes. However, the magnitude of these differences shows that relatively little Ig absorption occurred after 8-h in either genotype. After parturition calves from C cows and BF cows were fed proportionately 0.67 and 0.51 of the first milking colostrum yield, respectively. Nevertheless, the concentrations of Ig total in calf serum at 8 h were proportionately 0.96 and 0.85 for C and BF, respectively, of serum concentration at 48 h, despite the fact that calves were assisted to suckle (Experiment 2) or were fed (Experiment 3) at 8 h post-feeding. It is well established that Ig absorption by the calf decreases with time post partum. Logan *et al.* (1978) reported that 0.50 of maximum Ig concentrations may be attained by about 5 h after birth in beef calves. Stott *et al.* (1979) reported that dairy calves fed 2.0 l of colostrum post partum did not respond, in terms of Ig

absorption, to a second feeding 12 h later thus indicating that feeding 2 l supplied enough volume to satiate absorptive cells (pinocytotic cessation) in the intestine. Similarly, Langholz *et al.* (1987), reported that an increase in calf serum Ig concentration in suckled beef calves was observed only up to a consumption of 2 kg of colostrum. From a series of experiments Michanek (1994) suggested that a colostrum dose (40 to 50 ml/kg birth weight in that study) corresponding to at least 2 g IgG per 1 kg birth weight fed 1 h after birth appeared to be enough to accelerate the intestinal macromolecular closure process. Levels below this did not accelerate the closure process. As calves in the present study were offered 3 to 4 times that amount of IgG per 1 kg birth weight, this would help explain the relatively small increases in calf serum Ig concentration between 8 and 48 h. It is possible that calf serum Ig may have peaked at a higher concentration closer to 24 h (Vann *et al.*, 1995; Hopkins and Quigley, 1997) but this is not necessarily so (Delong *et al.,* 1979; Langholz *et al.,* 1987).

The genotype × experiment interaction for concentrations of calf IgG_1 and Ig total at 8-h post-feeding can be attributed to the magnitude of the differential in colostrum IgG_1 mass fed to each genotype. Similarly, the lower serum Ig concentrations at 48 h post partum in calves from C cows compared to calves from BF cows reflects the difference between the genotypes in the mass of colostrum Ig produced. Bush and Staley (1980) concluded that the Ig mass ingested per unit of bodyweight soon after birth is the most important factor determining Ig concentration in serum.

In conclusion, the lower immune status of calves from C cows than BF cows is attributed to both a lower colostrum yield and Ig concentration resulting in a considerably lower Ig mass produced by their dams. This lower immune status could be of concern in adverse environments.

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References

Birch, G.G and Mwangelwa, O.M. 1974. Calorimetric determination of sugars in sweetened condensed milk products. *Journal of the Science of Food and Agriculture* **25**: 1355–1362.

Bradley, J.A. and Niilo, L. 1984. A reevaluation of routine force-feeding of dam's colostrum to normal newborn beef calves. *Canadian Veterinary Journal* **25**: 121–125.

Bush, L.J. and Staley, T.E. 1980. Absorption of colostral immunoglobulins in newborn calves. *Journal of Dairy Science* **63**: 672–680.

DeLong, W.J., Waldhalm, D.G., Hall, R.F. and Everson, D.O. 1979. Restricted dietary protein in pregnant beef cows: II. Effect on the immune response. *Theriogenology* **12**: 69–77.

Devery-Pocius, J.E. and Larson, B.L. 1983. Age and previous lactations as factors in the amount of bovine colostral immunoglobulins. *Journal of Dairy Science* **66**: 221–226.

Earley, B., McGee, M., Fallon, R.J., Drennan, M.J., Murray, M. and Farrell, J.A. 2000. Serum immunoglobulin concentrations in suckled calves and dairy-herd calves. *Irish Journal of Agricultural and Food Research* **39**: 401–407.

Fahey, J.L. and McKelvey, E.M. 1965. Quantitative determination of serum immmunoglobulins in antibody-agar plates. *Journal of Immunology* **94**: 84–90.

Fallon, R.J., Harte, F.J. and Keane, M.G. 1989. Methods of artificially feeding colostrum to the new-born calf. *Irish Journal of Agricultural Research* **28**: 57–63.

Field, R.W., Bretzlaff, K.N., Elmore, R.G. and Rupp, G.P. 1989. Effect of induction of parturition on immunoglobulin content of colostrum and calf serum. *Theriogenology* **32**: 501–506.

Greene, H.J. and Bakheit, H.A. 1980. Many calf deaths can be prevented. *Farm and Food* **11**: 76–77.

Guy, M.A., McFadden, T.B., Cockrell, D.C. and Besser, T.E. 1994. Regulation of colostrum formation in beef and dairy cows. *Journal of Dairy Science* **77**: 3002–3007.

Halliday, R., Russel, A.J.F., Williams, M.R. and Peart, J.N. 1978. Effects of energy intake during late pregnancy and of genotype on immunoglobulin transfer to calves in suckler herds. *Research Veterinary Science* **24**: 26–31.

Hopkins, B.A. and Quigley, J.D. 1997. Effects of method of colostrum feeding and colostrum supplementation on concentration of immunoglobulins G in the serum of calves. *Journal of Dairy Science* **80**: 979–983.

Kruse, V. 1970. Yield of colostrum and immunoglobulin in cattle at the first milking after parturition. *Animal Production* **12**: 619–626.

Langholz, H.J., Schmidt, F.W., Derenbach, J. and Kim, J.W. 1987. Suckling behaviour, immunglobulin status and weaning performance in suckler cows. *World Review of Animal Production* **XXIII**: 33–38.

Logan, E.F. 1977. The influence of husbandry on colostrum yield and immunoglobulin concentration in beef cows. *British Veterinary Journal* **133**: 120–125.

Logan, E.F., McMurray, C.H., O'Neill, D.G., McParland, P.J. and McRory, F.J. 1978. Absorption of colostral immunoglobulins by the neonatal calf. *British Veterinary Journal* **134**: 258–262.

Logan, E.F., Meneely, D.J. and Lindsay, A. 1981. Colostrum and serum immunoglobulin levels in Jersey cattle. *British Veterinary Journal* **137**: 279–282.

Mancini, G., Carbonara, A.O. and Heremans, J.F. 1965. Immunochemical quantitation of antigens by single radial immunodiffusion. *Immunochemistry* **2**: 235–254.

Mannion, J., Phelan, J. and Crilly, J. 1987. Survey shows calf mortality at over six per cent. *Irish Farmers Monthly*, February: 26–29.

McCutcheon, G.A., Caffrey, P.J., Kelleher, D.L. and Brophy, P.O. 1991. Twinning in a suckler herd 2. Effects on cow and calf immunoglobulin status. *Irish Journal of Agricultural Research* **30**: 11–17.

McEwan, A.D., Fisher, E.W., Selman, I.E. and Penhale, W.J. 1970. A turbidity test for the estimation of immune globulin levels in neonatal calf serum. *Clinica Chimica Acta* **27**: 155–163.

McGee, M. 1997. Defining suckler systems in terms of efficiency of lean meat production and market requirements. *PhD Thesis*, National University of Ireland, 458 pages.

Michanek, P. 1994. Transfer of colostral immunoglobulin to newborn dairy calves: Effects of housing on suckling patterns and consequences for the intestinal transmission of macromolecules. *PhD Thesis*, Swedish University of Agricultural Sciences, Department of Agricultural Biosystems and Technology.

Norman, L.M., Hohenboken, W.D. and Kelley, K.W. 1981. Genetic differences in concentration of immunoglobulins G1 and M in serum and colostrum of cows and in serum of neonatal calves. *Journal of Animal Science* **53**: 1465–1472.

Olson, D.P., Bull, R.C., Everson, D.O. and Woodard, L.F. 1981a. Immunoglobulin levels in serum and colostral whey of protein-metabolisable energy restricted beef cows. *Research Veterinary Science* **30**: 49–52.

Olson, D.P., Bull, R.C., Kelley, K.W. and Woodard, L.F. 1981b. Effect of maternal nutritional restriction and cold stress on young calves: Absorption of colostral immunoglobulins. *American Journal of Veterinary Research* **42**: 876–880.

Petrie, L., Acres, S.D. and McCartney, D.H. 1984. The yield of colostrum and colostral gammaglobulins in beef cows and the absorption of colostral gammaglobulins by beef calves. *Canadian Veterinary Journal* **25**: 273–279.

Roy, J.H.B. 1990. Immunity to disease. In: "The Calf", 5th edition, Volume 1, Management of Health", (ed. Roy, J.H.B), Butterworths, pages 17–52.

Shell, T.M., Early, R.J., Carpenter, J.R. and Buckley, B.A. 1995. Prepartum nutrition and solar radiation in beef cattle: II. Residual effects on postpartum milk yield, immunoglobulin and calf growth. *Journal of Animal Science* **73**: 1303–1309.

Statistical Analysis Systems Institute 2001. SAS/STAT. The SAS system for windows, Release 8.02, SAS Institute Inc., Cary, NC, USA.

Stott, G.H., Marx, D.B., Menefee, B.E. and Nightengale, G.T. 1979. Colostral immunoglobulin transfer in calves. II. Rate of Absorption. *Journal of Dairy Science* **62**: 1766–1773.

Stott, G.H., Fleenor, W.A. and Kleese, W.C. 1981. Colostral immunoglobulin concentration in two fractions of first milking postpartum and five additional milkings. *Journal of Dairy Science* **64**: 459–465.

Vann, R.C., Holloway, J.W., Carstens, G.E., Boyd, M.E. and Randel, R.D. 1995. Influence of calf genotype on colostral immunoglobulins in *Bos taurus* and *Bos indicus* cows and serum immunoglobulins in their calves. *Journal of Animal Science* **73**: 3044–3050.

Zachwiegja, A., Szulc. T., Dobicki, A. and Nowakowski, P. 1997. Effect of different share of Charolais breed on cows colostrum composition and immunoglobulins level in the calves blood serum. *Proceedings of European Association for Animal Production – 48th Annual Meeting, Vienna,* 238.

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