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The measurement of serum immunoglobulin concentration to estimate lamb colostrum intake

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ABSTRACT

Colostrum is an essential post-natal energy source. We have investigated the link between lamb serum immunoglobulin concentration and colostrum intake as a means of estimating lamb energy intake.

Thirty previously unsuckled Coopworth and Corriedale lambs were bottle fed fresh colostrum at 60, 135, 210 or 285 ml/kg birth weight 24 hr in equal feeds at 2 or 4 hour intervals from birth to 30 hours after birth. IgG in serum was measured before first feeding and then at 8 hour intervals to 32 hours after first feeding by $ZnSO_4$ turbidity. Prior to feeding mean serum IgG concentration of the lambs was 0.41 ± 0.13 $g.l^{-1}$. IgG concentration increased linearly with increasing colostrum consumption up to 210 ml colostrum kg birth weight. A relationship between lamb serum IgG concentration and the volume of colostrum consumed was determined by linear calibration.

This technique was applied in the field to estimate the colostrum intake of 104 lambs aged between 16 and 32 hours. On the basis of a 95% confidence interval for the relationship between serum IgG concentration and colostrum intake it was found that a significant proportion (0.16) of the lambs received less than 210 ml/kg birth weight/24 hr of colostrum, a level insufficient for metabolic needs.

These results indicate underfed lambs can be identified by the concentration of IgG in their serum 16 hours after birth.

Keywords Colostrum; immunoglobulin; energy; lamb survival; linear calibration.

INTRODUCTION

Poor ewe maternal behaviour score has been linked to reduced lamb survival and weaning weight (O'Connor *et al.*, 1985) which may be due to lambs obtaining less colostrum in the first day of life. Lambs are born hypoimmunocompetent (Brambell, 1970) and with a small store of energy for heat production and metabolism and are dependent on colostrum to supply maternal immunoglobulins (Igs) and energy.

To establish if a relationship exists between ewe maternal behaviour score and the immune status and energy intake of lambs a non intrusive method of estimating colostrum intake had to be devised. This paper discusses an experiment in which a relationship was established between known colostrum intake and Igs in serum between birth and 32 hours. It was then used to estimate the colostrum intake in the first day of life of lambs in the field from a single blood sample at tagging 16-24 hours after birth.

MATERIALS AND METHODS

Calibration

20 mixed age Coopworth and Corriedale ewes showing signs of imminent parturition were placed in pens indoors where they gave birth. The udder was covered with a bag to prevent the lamb(s) suckling. Ewes were offered lucerne hay *ad lib* and supplied with drinking water. Colostrum was expressed by hand from the ewe at 6hr intervals, bulked with colostrum from other dams and stored at 37°C. The fresh colostrum was bottle fed to the lambs at one of 2 frequencies (2 hourly or 4 hourly) and at one of 4 volumes (60, 135, 210 or 285 ml/kg birth weight/24hr) the highest volume (285 ml/kg/24hr) was the highest natural intake of colostrum found in the literature (Mellor and Murray, 1985). Twin lambs were allocated the same colostrum volume but one lamb was fed 2 hourly and the other 4 hourly.

Lambs were blood sampled by venepuncture into a 5ml vacutainer (Becton Dickinson Vacutainer Systems, New Jersey, USA) before the first feeding and subsequently at 8 hour intervals (before a feed) to 30 hours after the initial feed. Serum was collected and stored at -70°C until analysed for total Ig by $ZnSO_4$ turbidity (McEwan *et al.*, 1970). IgG concentration of ewe colostrum was measured by the method of Fahey and McKelvey (1965) using single radial immunodiffusion (RID) kits supplied by ICP (Auckland, New Zealand).

Field study

One hundred and four lambs of 6 genotypes (Coopworth, Cpw; Corriedale, Cr; Booroola Merino x Coopworth, F1; Booroola Coopworth x Booroola Coopworth, F2; Booroola Merino-Coopworth x Coopworth, 1/4Br; Border-Corriedale, BdCr) were blood sampled once by 5 ml vacutainer at tagging approximately 16-24 hours after birth and 10 ml sample of dam colostrum collected. Lamb weight was recorded and at weaning, 10-12 weeks after birth.

RESULTS

Calibration

Lamb serum IgG concentration reflected the volume of colostrum consumed (Figure 1). Prior to feeding all lambs had a serum IgG concentration at or near zero (0.41 ± 0.13 g/l, n=29). Lambs fed colostrum at 60 ml/kg/24 hr exhibited no significant increase in serum IgG concentration over 32 hours. In contrast the serum of lambs fed greater volumes of colostrum did show a significant increase in IgG concentration with time and volume fed although there was no difference in response to the two higher volumes. Between 16 and 24 hours after the first feed the rate of increase in serum IgG concentration declined. Mean serum IgG concentration did not exceed 40 g/l.

Serum IgG was adjusted by regression to a common colostrum IgG concentration of 69 g/l, the average IgG concentration of colostrum fed to lambs. A weighted regression of lamb serum IgG concentration (16 hours after the first feed) against the volume of colostrum fed using the method of linear calibration (Snedecor and Cochran, 1980) shows serum IgG increased linearly with increasing colostrum consumption up to 210 ml/kg/24 hr, (Figure 2).

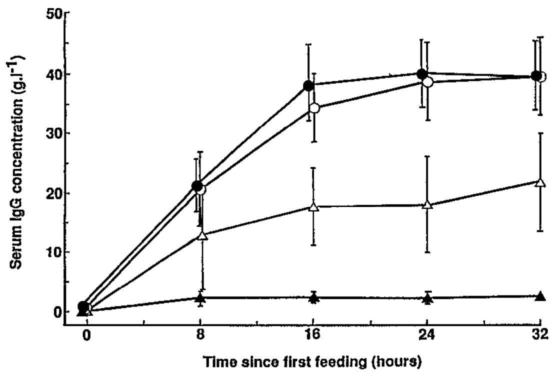

FIG 1 Appearance of IgG in serum of newborn lambs bottle fed colostrum at 60 ▲, 135△, 210 ● and 285 ○ ml/kg birth weight/24 hours.

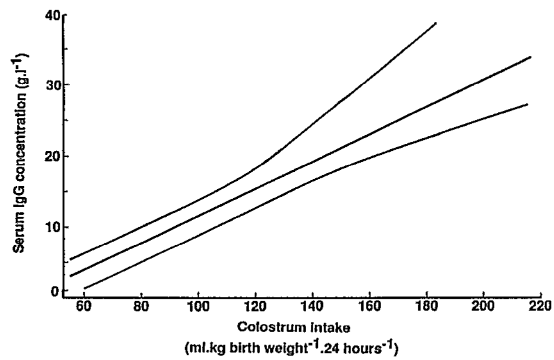

FIG 2 Calibration line and 95% confidence interval relating lamb serum IgG concentration to lamb colostrum intake. (Serum adjusted to a mean colostrum IgG concentration of 69 g/l). X predicted from Y using equation $X = 136 + (Y - 18.85)/0.191$.

Field study

Lamb serum IgG concentration exhibited a normal distribution about a flock mean of 40 g/l and standard deviation of 15.7 g/l (n=104). There was a significant effect of genotype ($P<0.05$) on lamb serum IgG concentration 16-24 hours after birth and a trend of lambs from larger litters having higher serum IgG concentrations. But correcting litter size for genotype reduced the litter size trend (Table 1).

TABLE 1 Mean lamb serum IgG concentration ($g.l^{-1}$).

Genotype effect (least squares means)	mean	se
Coopworth	52.7	6.2[a]
Booroola x Coopworth	47.1	5.2[b]
Booroola-Coopworth x Coopworth	48.6	5.0[b]
Booroola-Coopworth x Booroola-Coopworth	40.0	7.3[bc]
Border-Corriedale	42.0	5.5[bc]
Corriedale	31.5	5.9[c]
Litter size (raw means)		
1	35.5	2.9[a]
2	40.7	2.0[a]
3	44.5	3.7[a]
Litter size corrected for genotype effect		
1	38.5	3.4[a]
2	39.6	2.1[a]
3	40.8	4.3[a]

Means not followed by the same letter differ significantly ($P<0.05$)

Ewe colostrum IgG concentration

Ewe colostrum IgG concentration 16-24 hours after parturition was variable with a mean of 64.5 g/l and a standard deviation of 31.3 g/l (n=51). There were no significant relationships with breed, litter size, dam age or maternal behaviour score.

DISCUSSION

Ovine colostrum consists of three main Ig groups: IgG 91%, IgA 5% and IgM 3% (Smith *et al.*, 1975). Igs are non selectively absorbed and are found in the lymph of lambs in the same proportion as in colostrum (Brandon and Lascelles, 1971). $ZnSO_4$ turbidity measures total Igs and the RID kit supplied by ICP measures IgG only. Consequently Ig concentration of serum measured by $ZnSO_4$ was reduced by 9% to correspond to IgG only measured in colostrum.

The plateau in serum IgG concentration around 24 hours (Figure 1) after the first feed of colostrum was probably due to closure of the lamb intestinal wall (*jejunum*) to Igs at this time (Klobasa *et al.*, 1985). Boyd and Boyd (1987) found Ig takes 12 hours to be completely absorbed into calf blood serum from one feed of colostrum and multiple feeds prolong the period of absorption so delay the peak in serum Ig concentration to 24 hours (Halliday and Williams, 1976). The efficiency of absorption of colostral Ig into serum decreases with time. Lambs fed indoors had an efficiency of absorption of 27±3% at 24 hours after first feeding. Similar to published estimates of single lamb absorption efficiency at 30 hours, 24% (Shubber *et al.*, 1979b) and calf absorption efficiency at 24 hours; 23% (Boyd and Boyd, 1987) and 24% (Kruse, 1970).

In the indoor feeding experiment variation in serum Ig concentration was high between lambs receiving the same volume of colostrum (Figure 1). Cabello and Levieux (1981) found maturity of the lamb at birth influenced Ig absorption. Immature lambs (135-136 days gestation) had significantly higher serum Ig than lambs born at 144-145 days gestation. They also noted high thyreostimulin (TSH) levels at birth were correlated with low serum Ig concentration ($r= -0.79$, $P<0.01$). Using multiple regression techniques Kruse (1970) estimated 69-78% of the variation in serum Ig in calves was due to the amount of Ig ingested, the age of the calf when fed and the body weight of the calf.

In the field survey mean lamb serum Ig concentration for the six genotypes ranged from 31.5 to 52.7 g/l. This is comparable with Klobasa *et al.*, (1985) who measured means of 20 to 48 g/l for 6 European sheep breeds but higher than indoor lamb serum Ig concentrations. Lambs indoors may have been fed colostrum with a lower Ig concentration (69±2 g/l) than that ingested by Cpw, F1 and F2 lambs in the field. Presuckling colostrum samples were not collected in the field because of potential interference with a behaviour trial running concurrently. Colostrum Ig concentration decreases rapidly from 200+ g/l to 40 g/l after 12 hours and 3 bouts of suckling (Shubber *et al.*, 1979b) indicating very high colostrum Ig concentrations in the first few hours when the lamb's absorption efficiency is greatest.

Mean serum Ig concentration increased with increasing litter size but when variation due to breed was removed no difference between litter means existed. This is probably due to breed variation in colostrum Ig concentration because triplets do not drink more than singles (Shubber *et al.*, 1979a). Alternatively lambs from larger litters are born at a younger gestational age so have a gut more permeable to Igs (Blackmore, 1969).

The mean Ig concentration of lamb serum of 40 g/l found in the field study represents a colostrum intake well above the 210 ml/kg/24hr Mellor and Cockburn (1986) suggest is needed for lambs to survive at temperatures below 10°C. On the basis of the lower 95% confidence interval a serum Ig concentration of 26 g/l 16 hours after the first suckle corresponds to an intake of 210 ml.kg/24hr (885 kJ.kg ME). 16 lambs in the field study flock of 104 had a blood serum Ig concentration less than 26 ME^{-1} indicating these "low" lambs were at risk of death due to their body energy reserves being depleted at temperatures below 10°C. Considering only field study lambs born at an air temperature below 10°C (n=32); 2 of 6 lambs with a serum Ig concentration less than 26 g/l died (33%) compared with 2 of 26 (8%) lambs with a serum Ig concentration greater than 26 g/l.

These results indicate the volume of colostrum and energy ingested by a newborn lamb can be estimated from the concentration of IgG in the lamb serum 16 hours after the first feed. A field study showed 16% of lambs to have colostral intakes below optimum. But no relationship between maternal behaviour score of the dam and volume of colostrum ingested by her lambs was found.

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