MATERNAL IMMUNOGLOBULINS TRANSFER AND NEONATAL LAMB MORTALITY - A REVIEW

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ABSTRACT

The maternal immunoglobulins acquired through the colostrum play a significant role in the defense mechanism of lamb against neonatal diseases until its own immune system is primed and produces significant amount of antibodies. The absorption of these immunoglobulins from the intestine is maximum during first six hours of life and no absorption occurs 24-36 hours postpartum. Neonatal lambs with failure or partial failure of passive transfer of immunoglobulins have higher rate of morbidity and mortality. Litter size and birth weight has significant effect on the absorption of immunoglobulins and mortality rate. The concentration of these maternal immunoglobulins in circulation at 24 hours after birth can be used as an indication of immunity or susceptibility of lambs to neonatal diseases. Several tests like zinc sulphate turbidity test, sodium suplhate turbidity test, refractometery, glutaraldehyde coagulation test, latex agglutination test, radioimmuno diffusion, radioimmunoassay, electrophoresis and ELISA have been developed for determination of immunoglobulin status. Among these, zinc sulphate turbidity test is simple to perform in laboratory and refractometery under field conditions.

INTRODUCTION

The immune system of the lamb is fully developed well before birth but is in unprimed state (Tizard, 1992). The maternal immunoglobulins acquired through the colostrum play a significant role in the defence mechanism of new born lamb until its own immune system is primed and produces significant amount of antibodies. With the onset of immunoglobulins synthesis, IgG_1 is detected in the serum of colostrum-deprived neonatal lambs within a week of birth whereas appearance of IgG_2 is delayed until three to four weeks postpartum (Varela-Diaz and Soulsby, 1972). However, significant concentration of antibodies to protect against infections takes longer time and losses due to acquired neonatal infections are about 8-14.5 per cent (Johnston *et al.*, 1980; Purvis *et al.*, 1985).

Colostrum is not only rich in immunoglobulins as compared to milk (Table 1) but is also an excellent source of energy, vitamin A and essential minerals (Khan and Khan, 1996).

Lamb requires between 180 and 210 ml of colostrum/Kg body weight during first 18 hours after birth in order to provide sufficient fuel for heat production (Mellor and Murray, 1986). Eales *et al.* (1980) were of the view that adequate supply of colostrum prevents hypothermia more effectively than providing shelter. Losses due to hypothermia are much higher upto 34 (Purvis *et al.*, 1985) and 43 per cent (Johnston *et al.*, 1980). Colostrum intakes of this order usually provide enough immunoglobulins for protection against field infections. The septicaemic/bacteraemic deaths are related to a deficiency of IgM whereas IgG deficiency is associated with diarrhoea and re-excretion of IgA helps in stopping the diarrheoic process (Fisher, 1980). A small amount of colostral IgG after being absorbed is secreted in the nasal and lacrimal secretions of lambs which play a valuable role in preventing respiratory infections before active local production of IgA and IgM at 2-3 weeks of age (Wells *et al.*, 1975; Smith *et al.*, 1976). Colostrum absorption also increases the number and opsonization activity of neutrophils (Bernadina *et al.*, 1991).

Absorption of immunoglobulins

Ideally the maternal immunity should be transferred *in utero* to their foetuses so that they are brought into the world protected against the microorganisms (Fisher, 1980). Placental barriers do not allow to pass immunoglobulins from dams to the neonates in ruminants (Khan and Khan, 1991b), therefore, the lamb has to depend entirely on antibodies received via colostrum (Butler, 1973). Immunoglobulins are not detected in the serum of lambs before the first intake of colostrum (Klobasa and Werhahn, 1989), however, according to Reid (1972), Sawyer *et al.* (1977), Czarnecki *et al.* (1991) and Waelchli *et al.* (1994) traces of immunoglobulins are found in lambs serum at birth probably due to *in utero* infections.

The level of proteolytic activity in the digestive tract of young animals is low and is further reduced by trypsin inhibitors present in colostrum (Tizard, 1992). Therefore, colostral proteins without degradation reach the small intestine where they are taken up by the epithelial cells by micro-pinocytosis and passed through enterocytes into the intestinal lymphatics and capillaries

Table 1: Concentration (mg/ml) of various classes of immunoglobulins in various body fluids of dams and neonatal lambs.

	IgG	IgM	IgA	Reference
Ewe				
Blood	21.8±0.53	1.87±0.18	0.37±0.06	Fedorov (1983)
Serum	17.80	5.06	-	Sawyer *et al.* (1977)
Milk	0.6-1	0-0.07	0.05-0.12	Tizard (1992)
Colostrum				
	40-60	4-12	1-7	Tizard (1992)
	136.80	16.02	-	Sawyer *et al.* (1977)
Neonatal Lambs				
At birth serum	0.22	0.21	-	Sawyer *et al.* (1977)
24 hr post colostrum ingestion				
Blood	24.70±0.68	3.7±0.23	1.5±0.11	Fedorov (1983)
Serum	21.31	5.58	-	Sawyer *et al.* (1977)

(Khan and Khan, 1991a). The intestine is unselectively permeable, therefore, all immunoglobulins isotypes can be absorbed (Sawyer *et al.*, 1977). However, IgA is gradually re-excreted. The permeability remains highest immediately after birth to 6 hours of life. Then immature foetal type of cells capable of transfer of intact immunoglobulins are gradually replaced by a digestive type of cells (Tizard, 1992). Smeaton and Simpson-Morgan (1985) also observed that the layer of cells responsible for absorption of colostral antibodies progressively disappears from the villi, resulting in closure which usually completes 24-36 hours after birth (Khan and Khan, 1991b). So lambs absorb intact immunoglobulins from ingested colostrum only during the first day of life (Klobasa *et al.*, 1986). Trakair and Robinson (1989), however, reported that although the small intestine of sheep is relatively mature at birth, there are still vacuolated enterocytes present for at least 2 days in distal regions where these cells possess a range of vesicle morphology which might be indicative of at least two separate routes for enterocytes handling of proteins taken up from the lumen. The localisation of immunoreactive immunoglobulins within the enterocytes, presumable of colostral or milk origin, in both proximal (non-vacuolated) and distal (vacculated) regions, does not follow patterns which suggest orderly renewal at closure. The study suggested that closure is not solely brought about by epithelial cell replacement.

Immunoglobulins reach peak level on day 1 of lamb life, then decline during the next 3 weeks (Smith *et al.*, 1976). The decline of maternal immunoglobulins in lamb serum overlaps with the onset of lamb immunoglobulins synthesis as renewed rises are observed for IgG_2, IgM and IgG_1, after 2, 3 and 7 weeks, respectively. IgA remained at low levels characteristic of adult sheep (Klobasa and Werhahn, 1989).

Concentration of immunoglobulins in serum of lambs at various intervals was studied after one hour colostrum feeding by Halliday and Williams (1976). They observed positive effects of second feeding on the absorption of antibodies (Fig. 1). According to Klobasa *et al.* (1994), feeding at 2 hours intervals produced maximum immunoglobulin concentration at 30 hours while 6 hours feeding intervals achieved the same maximum levels at 24 hours. Concentrations of IgG and IgM in ewe serum do not correlate with those in the colostrum as the later contains abundant amounts of immunoglobulins, with IgG being selectively concentrated cover IgM (Smith *et al.*, 1975; 1976; Sawyer *et al.*, 1977).

According to Varela-Diaz and Soulsby (1972) IgG_1 is transferred into colostrum of ewe, this is why among IgG_1 and IgG_2, the former is predominant in colostrum as well as in the serum of lambs after colostrum ingestion (Schmerr and Goodwin, 1991).

All the IgG, most of IgM and about half of the IgA of colostrum are derived from serum (Tizard, 1992), the rest being produced locally in the udder by plasma cells which are located in close association with glandular epithelium (Watson and Lascelles, 1973). Passive immunization of lambs is positively related to

colostral IgG contents before suckling (Esser *et al.*, 1989). Similarly, McGuire *et al.* (1983) reported that the mean serum IgG_1 concentration in lambs was significantly lower from ewes with the lowest postpartum and presuckle colostrum IgG_1 concentrations (<30 mg/ml) than mean serum IgG_1 concentration in lambs from ewes with the highest postpartum, presuckle colostrum IgG_1 concentrations (> 110 mg/ml).

Sawyer *et al.* (1977) found no relationship between immunoglobulins in the colostrum and serum of lambs at 24 hours of age, they suggested that absorption is not restricted by amount of immunoglobulins in the colostrum but by absorption factors in the gut, provided that the amount ingested is adequate. The absorption factors in the gut includes absorption time after birth, competetion between *E. coli* and immunoglobulins for common intestinal receptors and physical binding of colostral immunoglobulins by intestinal microbs within the intestinal lumen which also inhibit availability of transportable immunoglobulins (Khan and Khan, 1991a).

Colostrum production ranges from 1216 to 4493 g per ewe during first 24 hours after parturition which contains 22.21 to 86.34 g of immunoglobulins. The immunoglobulin contents of colostrum fall rapidly after the first suckling and reach a low level 36 hours after the first feed and being replaced by whey contents during this period (Shubber and Doxey, 1979). Colostrum production is related to nutritional status of ewe during preganncy. Ewes which are well fed during late pregnancy produce more colostrum than their lambs need but in most under fed ewes, the lambs requirement for colostrum exceed the ewes production (Mellor and Murray, 1986; AL-Sabbagh *et al.*, 1995).

Neonatal lamb mortality

Failure of passive transfer of immunoglobulins to neonatal lambs has significant effect on neonatal mortality and losses due to infectious causes are positively correlated with low concentrations of serum immunoglobulins. Hodgson *et al.* (1992) reported that morbidity and mortality rates were higher in colostrum-deprived lambs (80 and 67 %) than colostrum fed lambs (20 and 13 %). According to Vihan (1986), 20 per cent of colostrum-deprived lambs die within first week of life.

Colostrum consumption by individual lamb is related to litter size. The smaller the litter size, the greater is the amount ingested (Shubber *et al.*, 1979). As the serum immunoglobulin concentration is directly related to quantity of colostrum ingested by the lamb (Esser *et al.*, 1989; Otesile and Oduye, 1990), therefore, serum immunoglobulin concentration decreases as the litter size increases (Fig. 2) (Findlay, 1973; Halliday, 1976; Logan and Irwin, 1977; Gilbert *et al.*, 1988). First born lamb from twins, triplets or quadruplets has very high immunoglobulin levels than the single born lamb (Logan and Irwin, 1977) due to the fact that amount of colostrum produced and immunoglobulin contents increase as litter size increases (Halliday, 1976). Werhahn and Klobasa (1982) reported that losses increases with number of lambs born per ewe: singles (4.7 %), twins (10.7 %), triplets (12.5%) and quadruplets (50%) (Fig.2). Similar findings had also been reported by other workers (Harker, 1973; Petersson, 1982; Hinch and Owens, 1984; Lecrivain and Janeau, 1988).

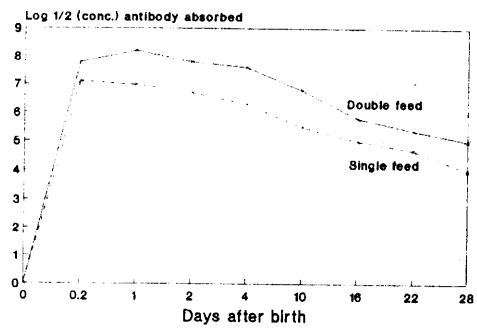

Fig. 1: Means ± SEs of anti-egg albumin concentrations in sera from lambs given only colostrum at 1 h of age (single feed) and lambs given a second feed without added antibody at 7 h (double feed) Source: Halliday and Williams (1976).

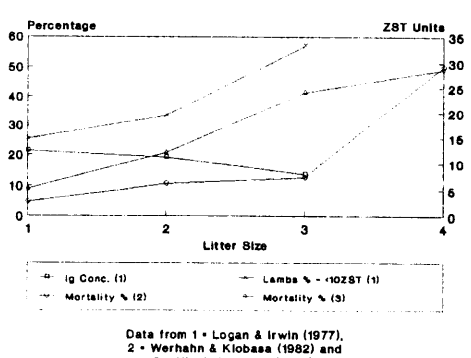

Fig. 2: Relationship of litter size with immunoglobulin concentration (ZST units), lambs (%) with less than 10 ZST units and neonatal lambs mortality.

Harker (1973) established a relationship between serum immunoglobulin concentration in lamb with that

of birth weight. The mean serum immunoglobulin concentration in lambs are 29.5 ZST units in those upto 2 Kg birth weight, 39 in 2-3 Kg, 45.6 in 3-4 Kg and 41.5 units in those over 4 Kg (Fig. 3). Highest mortality (36.8%) upto two weeks of age in lambs with low (1.5 Kg) birth weight and 10.2 % with 4 Kg birth weight was reported. Moreover, mortality rate increases (33.3%) with body weight exceeding 5.5 Kg.

According to Hinck and Owens (1984), the mortality of single, twin, triplet and quadruplet lambs were 9.0, 20.8, 41.3, and 49.1 per cent at mean birth weight of 4.6, 3.5, 2.8 and 2.4 Kg, respectively. Knight *et al.* (1988) observed that single lambs were heavier than twins, 4.98 vs 4.05 Kg and incidence of infection was higher in twins than single lambs, 4.2 vs 1.8 per cent. Similarly, Woolliams *et al.* (1983) and Purser and Young (1983) observed lamb mortality to be higher in low mean birth weights than those with higher mean birth weights. According to Ducrot *et al.* (1989) mortality was four times higher in lambs weighing < 2.5 Kg at birth than in lambs weighing over 2.5 Kg. Lambs with birth weight of 3.5 Kg and above survive best (Dalton *et al.*, 1980).

Absorption of immunoglobulins with relation to sex is controversial in literature. Sawyer *et al.* (1977) reported that immunoglobulins concentration was slightly higher in female than male lambs 24 hours after colostrum ingestion. Similarly, the mortality rate was higher in males than in females, 4.82 vs 3.92 (Khan, 1990), 59.38 vs. 46.92 per cent (Shrivastava *et al.*, 1983) and 8.83 vs. 8.69 per cent (Juma *et al.*, 1974). On the other hand, Halliday and Williams (1979) reported more efficient immunoglobulin absorption in males than females. Cinpercescu (1977), however, was unable to find any relationship between sex and immunoglobulin absorption, Similarly, Malik *et al.* (1980) and Poonia *et al.* (1983) were unable to find any singnificant relation between sex and survival.

There is a wide distribution in the level of circulating maternal immunoglobulins 24 hours after the ingestion of colostrum and quite a large proportion of lambs are hypogammaglobulinaemic, < 10ZST units (Reid, 1972).

According to Bekele *et al.* (1992), failure and partial failure of Ig transfer from dam to lambs are observed in 1.8 and 15.3 per cent lambs, respectively. Passive transfer failure was observed in 14 per cent apparently healthy lambs and in 46 per cent of lambs dying of natural causes between 24 hours and 5 weeks of age (Sawyer *et al.*, 1977). The results of Logan and Irwin (1977) show that 20.2 % lambs were hypogammaglobulinaemic and were more susceptible to neonatal diseases. Findlay (1973) observed that all lambs with immunoglobulins less than 20 ZST units die during first week of life. Mortality in lambs with 20-40 ZST units was very low and no mortality in lambs with 50 ZST units. According to Reid (1972), 5.5 per cent lambs with concentration of less than 10 ZST units are likely to die during first week of life (Fig. 4). Villar and Vulich (1980) reported that 0-20 ZST units is indication of high risk of subsequent death in lambs, nearly 20 per cent of all lambs fall within this range at the age of 48 hours and 40 per cent at 7 days of age.

Study in neonatal calves also demonstrated that neonates with a serum ZST values < 20 units are very susceptible to diseases (Gay *et al.*, 1965). According to Khan (1995) mortality was three times in buffalo and cow neonates having intermediate IgG_1 concentration (0.41-1.69 g/dL) and as high as nine times in neonates with low IgG_1 concentration (< 0.4 g/dl) as compared to neonates having high IgG_1 (> 1.7 g/dl). Esser *et al.* (1989) reported that mean serum IgG contents at 24 hours after suckling in lambs those died were lower (25.3±15 mg/ml) than in those survived (33.1±15.1 mg/ml).

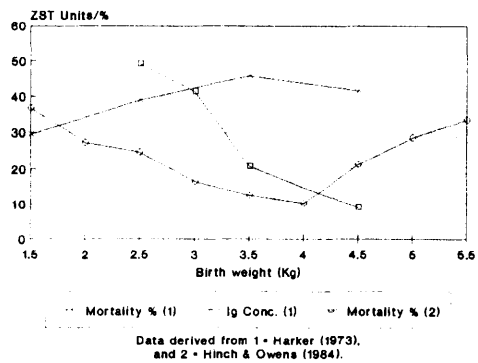

Fig. 3: Relationship of immunoglobulins concentration (ZST units) and mortality (%) with birth weight of lambs.

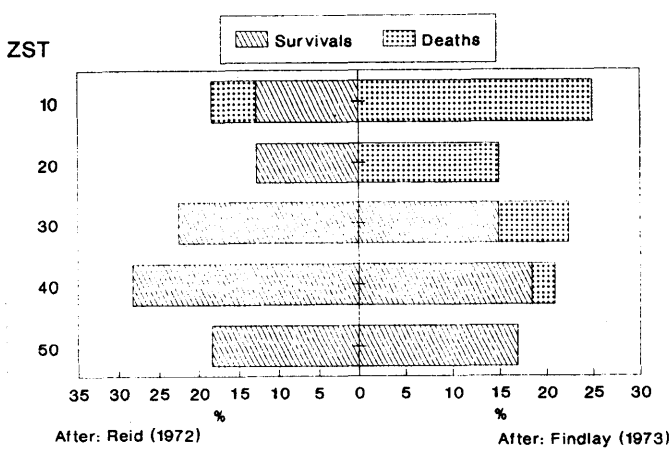

Fig. 4: Relationship of serum immunoglobulins with survival and mortality rates of neonatal lambs during first week of life.

McGuire *et al.* (1983) observed that 45 per cent lambs die before 3 weeks of age with < 6 mg/ml of immunoglobulins in their serum at 24 to 36 hours of age as compared to 5 per cent of those lambs with adequate passive transfer of immunoglobulins. Immunoglobulins concentration in serum of lambs those died was 9.2 and 1.4 mg/ml of IgG_1 and IgM compared with 36.2 and 6.1 mg/ml, respectively, in surviving lambs (Werhahn and Klobasa, 1982).

Determination of hypogammaglobulinaemia

Several tests like zinc sulphate turbidity (ZST) test, refractometry, glutaraldehyde coagulaion test (GCT), latex agglutination test (LAT), radio immunodiffusion (RID), radioimmunoassay (RIA), electrophoresis and ELISA have been developed for determination of immunoglobulins status of neonates.

The ZST test is simple to perform and can be correlated with the immune status of the lamb (Reid, 1972; Logan and Irwin, 1977; Findlay, 1973; Harker, 1973). Serum hemolysis is the only serious problem encountered with ZST (Gitter and Stone, 1969).

The ZST test is simple to use in the laboratory but at the farm the refractometer can easily be used which gives the reading of total protein in the serum or plasma. As the level of albumin is fairly constant in young lambs, so the instrument indirectly gives an indication of the amount of globulin present. There is a positive correlation between values obtained by this method and those obtained by standard ZST method (Reid and Clifford, 1974; Reid and Martinez, 1975).

Pfeiffer *et al.* (1977), Naylor and Kronfeld (1977) and Rea *et al.* (1996) compared the single RID, ZST, serum electrophoresis and refractometer methods for the quantitation of calf immunoglobulins. They found that single RID proved useful for quantitation when either class or subclass information are needed. Zinc sulphate turbidity measurements gave accurate results for total immunoglobulin concentration.

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REFERENCES

Al-Sabbagh, T. A., L. V. Swanson and J. M. Thompson, 1995. The effect of ewe body condition at lambing on colostral immunoglobulin G concentration and lamb performance. J. Anim. Sci., 73: 2860-2864.

Bekele, T., E. B. Otesile and O. B. Kasali, 1992. Influence of passively acquired colostral immunity on neonatal lamb mortality in Ethiopian highland sheep. Small Ruminant Res. (Africa), 9: 209-215.

Bernadina, W. E., M. A. W. Van Leeuwen, W. M. L. Hendrikx and E. J. Rutienberg, 1991. Serum opsonic activity and neutrophil phagocytic capacity of newborn lambs before and 24-36 h after colostrumuptake. Vet.Immun.Immunopath.,29:127-138.

Butler, J. E., 1973. Synthesis and distribution of immunoglobulins. J. Am. Vet. Med. Assoc., 163: 795-798.

Cinpercescu, D. D., 1977. Dynamics of serum immunoglobulin concentrations in sheep during pregnancy and lactation. Res. Vet. Sci., 22: 23-27.

Czarnecki, A., A. Gluszak, K. Radymska-Wawrzyniak, A. Rybka and T. Studzinski, 1991. Changes in erythrocytes, leukocytes and immunoglobulins in Polish lowl and longwool lambs during the postnatal period. Medycyna Weterynaryina, 47: 90-92.

Dalton, D. C, T. W. Knight and D. L. Johnson, 1980. Lambs survival in sheep breads on New Zealand hill country. N. Z. J. Agri. Res., 23: 167-173 .

Ducrot, C., B. Arnould, C. Berthelon and D. Calavas, 1989. Establishment of risk factors in perinatal mortality of lambs in a survery of 92 sheep flocks in sourtheastern France. Epidemiologie et sante Animale, 16: 57-75 (Vet. Bull., 60: 3579, 1990).

Eales, F. A., J. Small and R. H. Armstrong, 1980. Plasma composition in hypothermic lambs. Vet. Rec., 106: 310.

Esser, D., F. W. Schmit, S. Von Korn and K. J. Peters, 1989. Immunoglobulin G status of ewes and their lambs. J. Anim. Breed. Gen., 106: 120-128.

Fedorov, Yu, N., 1983. Characteristics of immunoglobulins of small ruminants. Trudy Vsesoyuznogo Instituta Eksperimental'noi Veterinarii, 57: 14-20 (Vet. Bull., 55: 1669, 1985).

Findlay, C. R., 1973. Serm immune globulin levels in lambs under a week old. Vet. Rec., 92: 530-532.

Fisher, E. W., 1980. Neonatal survival. Br. Vet. J., 136: 585-589.

Gay, C. C., N. Andreson, E. W. Fisher and A. D. McEwan, 1965. Gamma globulin levels and neonatal mortality in market calves. Vet. Rec., 77: 148-149.

Gilbert, R. P., C. T. Gaskins, J. K. Hillers, C. F. Parker and T. C. McGuire, 1988. Genetic and environmental factors affecting immunoglobulin G_1 concentrations in ewe colostrum and lamb serum. J. Anim. Sci., 66: 855-863.

Gitter, M. and S. S. Stone, 1969. The effect of haemoglobulin on the detection of immunoglobulins in calf sera. Br. Vet. J., 125: 458-462.

Halliday, R. 1976. Variations in immunoglobulin concentrations in Finnish x Dorset Hron lambs. Res. Vet. Sci., 21: 331-334.

Halliday, R. and M. R. Williams, 1976. Passive immunity in the lamb. Effects of a second feed of colostrum on antibody absorption from the first feed. Res. Vet. Sci., 21: 173-175.

Halliday, R. and M. R. Williams, 1979. The absorption of immunoglobulin from colostrum by bottle-fed lambs. Annales de Recherches Veterinaires, 10: 549-556 (Vet. Bull., 50: 7704, 1980).

Harker, D. B., 1973. Serum immune globulin levels in lambs under a week old. Vet. Rec., 93: 431.

Hinch, G. N. and J. L. Owens, 1984. Factors affecting lamb mortality in high fecundity flocks. Annual Report 1982/83. Agricultural Research Division, New Zealand Ministry of Agriculture and Fisheries, pp: 260.

Hodgson, J. C., G. M. Moon, L. A. Hay and M. Quirie, 1992. Effectiveness of substitute colostrum in preventing disease in newborn lambs. Occassional Publication - British Society of Animal Production, 15: 163-165.

Johnston, W. S., G. K. Maclachlan and I. S. Murray, 1980. A survey of sheep losses and their causes on commercial farms in the north of Scotland. Vet. Rec., 106: 238-240.

Juma, K. H., J. Eliya, A. A. AL-Rawi and H. N. Abumaaly, 1974. Survival of lambs in Awassi sheep. Indian J. Anim. Sci., 44: 252-256.

Khan, A and M. Z. Khan, 1991a. Immunoglobulins in relation to neonatal calf mortality. Pakistan Vet. J., 11: 153-162.

Khan, A. and M. Z. Khan, 1991b. Aetiopathology of neonatal calf mortality. J. Islamic Acad. Sci. (Turkey), 4: 159-165.

Khan, A.; 1995. Studies on the bacterial aetiopathology of mortality in buffalo and cow neonates. Buff. Newsletter (Italy), 4: 13-14.

Khan, A. and M. Z. Khan, 1996. Neonatal calf mortality in Pakistan: III: Immunoglobulins in relation to mortality in buffalo and cow neonates. Buffalo J., 12: 243-252.

Khan, F. S., 1990. Comparative study of factors contributing to the mortality in lambs and kids. M. Sc. (Hons) Thesis, Deptt. Livestock Management, Univ. of Agri., Faisalabad, Pakistan, pp: 65.

Klobasa, F., E. Werhahn and E. Kallweit, 1986. Patterns of immunoglobulin concentrations in lamb serum from birth through the post-weaning period. In: Factors affecting the survival of new born lambs. G. Alexander, J. D. Barker and J. Slee (eds). Commission of the European Communities; Luxembourg. pp: 55-62.

Klobasa, F. and E. Werhahn, 1989. Variations in the concentrations of IgG_1, IgG_2, IgM and IgA immunoglobulins in sheep. 2. Changes in the blood of lambs of different breeds and crosses during the rearing period. Berliner und Munchner Tierarztiche Wochenschrift, 102 (10): 331-337 (Vet. Bull., 60: 4210, 1990).

Klobasa, F., H. Greimann and E. Kallweit, 1994. Investigation on the quantitative transfer of immunoglobulins from the intestines into the blood serum of newborn lambs. Berliner und Munchener Tiearztliche Wochenschrift, 107: 408-413 (Vet. Bull., 66: 2580, 1996).

Knight, T. W., P. R. Lynch, D. R. H. Hall and H. U. P. Hockey, 1988. Identification of factors contributing to the improved lamb survival in Marshall Romney sheep. N. Z. J. Agri. Res., 31: 259-271.

Lecrivain, E and G. Janeau, 1988. Neonatal mortality in lambs born in the open with out assistance. INRA Prod. Anim., 1: 331-338.

Logan, E. F. and D. Irwin, 1977. Serum immunoglobulin levels in neonatal lambs. Res. Vet. Sci., 23: 389-390.

Malik, R. C., R. N. Singh, R. M. Acharya and O. P. Dutta, 1980. Factors affecting lamb survival in crossbred sheep. Tr. Anim. Hlth. & Prod., 12: 217-223.

McGuire, T. C., J. Regnier, T. Kellom and N. L. Gates, 1983. Failure in passive transfer of immunoglobulin G_1 to lambs: measurement of immunoglobulin G_1 in ewe colostrums. Am. J. Vet. Res., 44: 1065-1067.

Mellor, D. J. and L. Murray, 1986. Making the most of colostrum at lambing. Vet. Rec., 118: 351-353.

Naylor, J. M. and D. S. Kronfeld, 1977. Refractometry as a measure of the immunoglobulin status of the newborn dairy calf : comparison with the zinc sulfate turbidity test and single radial immunodiffusion. Am. J. Vet. Res., 38: 1331-1334.

Otesile, E. B. and O. O. Oduye, 1990. Studies on factors affecting absorption of colostral immunoglobulins in newborn lambs. Bull. Anim. Hlth. & Prod. (Africa), 38: 447-452.

Petersson, C. J., 1982. Lamb mortality in four breeds. Farskotsel, 62: 16-17.

Pfeiffer, Nancy E., T. C. McGuire, R. B. Bendel an d J. M. Weikel, 1977. Quantitation of bovine immunoglobulins : Comparison of single radial immunodiffusion, zinc sulfate turbidity, serum electrophoresis and refractometer methods. Am. J. Vet. Res., 38: 693-698.

Poonia, J. S., B. Singh and D. S. Balaine, 1983. Studies on preweaning mortality in lambs of Nali and its crosses with Corriedale and Russian Merino. Livestock Adviser, 8: 7-10.

Purser, A. F. and G. B. Young, 1983. Mothering ability in two hill flocks. Br. Vet. J., 139: 296-306.

Purvis, G. M., F. D. Kirby, D. C. Ostler, J. Baxter and J. Bishop, 1985. Causes of lamb mortality in a commercial lowland sheep flock. Vet. Rec., 116: 293-294.

Rea, D. E., J. W. Tyler, D. D. Hancock, T. E. Besser, L. Wilson, D. S. Krytenberg and S. G. Sanders, 1996. Prediction of calf mortality by use of tests for passive transfer of colostral immunoglobulin. J. Am. Vet. Med. Assoc., 208: 2047-2049.

Reid, J. F. S., 1972. Serum immune globulin concentrations of newborn Hill lambs. Vet. Rec., 90: 371-372.

Reid, J. F. S and D. J. Clifford, 1974. Use of the refractometer in estimating immune globulin levels of neonatal lamb serum. Vet. Rec., 95: 22-23.

Reid, J. F. S. and A. A. Martinez, 1975. A modified refractometer method as a practical aid to the epidemiological investigation of disease in the neonatal ruminant. Vet. Rec., 96: 177-179.

Sawyer, M., C. H. Willadsen, B. I. Osburn and T. C. McGuire, 1977. Passive transfer of colostral immunoglobulins from ewe to lamb and its influence on neonatal lamb mortality. J. Am. Vet. Med. Assoc., 171: 1255-1259.

Schmerr, M. J. F. and K. R. Goodwin, 1991. Separation of ovine IgG_1 and IgG_2 on protein A-sepharose. Comp. Immuno. Micro. Inf. Dis., 14: 289-295.

Shrivastava, C. P., S. P. Prasad, L. B. Singh and B. C. Patnayak, 1983. Mortality in Marwari lambs grazing exclusively in range land of hot arid region. Indian J. Anim. Sci., 53: 681-683.

Shubber, A. H., D. L. Doxey, W. J. M. Black and J. Fitzsimons, 1979. Colostrum production of ewes and the amounts ingested by lambs. Res. Vet. Sci., 27: 280-282.

Shubber, A. H and D. L. Doxey, 1979. Immunoglobulin levels in ewe colostrum and in lamb serum. Res. Vet. Sci., 27: 283-285.

Smeaton, T. C. and M. W. Simpson-Morgan, 1985. Epithelial cell renewal and antibody transfer in the intestine of the foetal and neonatal lamb. Aust. J. Exp. Biol. Med. Sci., 63: 41-51.

Smith, W. D., P. W. Wells and C. Burrells and A. McL. Dawson, 1976. Maternal immunoglobulins and parainfluenza 3 virus inhibitors in nasal and lachrymal secretions and serum of newborn lambs. Cli. Exp. Immuno., 23: 544-553.

Smith, W. D., A. M. Dawson, P. W. Wells and C. Burrels, 1975. Immunoglobulin concentrations in ovine body fluids. Res. Vet. Sci., 19: 189-194.

Tizard, Ian, 1992. Veterinary Immunology: An introduction. 4th Ed., W. B. Saunders Company, London. pp: 248-257.

Trakair, J. F. and P. M. Robinson, 1989. Enterocyte ultrastructure and uptake of immunoglobulins in small intestine of the neonatal lamb. J. Anat., 166: 103-111.

Varela-Diaz, V. M. and E. J. L. Soulsby, 1972. Immunoglobulin synthesis in sheep. IgG_2 deficiency in neonatal lambs. Res. Vet. Sci., 13: 99-100.

Vihan, V. S., 1986. Sheep and goat immunoglobulins and their effect on neonatal survivability and performance. World Rev. Anim. Prod., 22: 65-68.

Villar, J. A. and S. A. Vulich, 1980. Mortality in newborn lambs: immunoglobulin values in Corriedale lambs up to one week of age. Revista de Medicina Veterinaria Argentina, 61(1): 21-26.

Waelchli, R. O., C. Muller, M. Hassig and P. Rusch, 1994. Immunoglobulin concentrations in colostrum and serum of lambs of dairy sheep breeds. Vet. Rec., 135: 16-17.

Watson, D. L. and A. K. Lascelles, 1973. Mechanisms of transfer of immunoglobulins into mammary secretion of ewes. Aust. J. Exp. Bio. Med. Sci., 51: 247-254.

Wells, P. W., A. McL. Dawson, W. D. Smith and B. S. W. Smith, 1975. Transfer of IgG from plasma to nasal secretions in newborn lambs. Vet. Rec., 97: 455.

Werhahn, E. and F. Klobasa, 1982. Rearing losses and the supply of lambs possessing maternal immunoglobulins. Tierziichter, 34: 462-463. (Vet. Bull., 53: 2085, 1983).

Woolliams, C., G. Wiener and N. S. M. Macleod, 1983. The effects of breed, breeding system and other factors on lamb mortality. 3. Factors influencing the incidence of weakly lambs as a cause of death. J. Agri. Sci. (UK), 100: 563-570.