IJAS Iranian Journal of Applied Animal Science

Relationship between Immunoglobulin Concentrations in the Ewe's Serum and Colostrum, and Lamb's Serum in Lori-Bakhtiari Sheep

Research Article

M. Vatankhah[1*]

[1] Department of Animal Science, Agriculture and Natural Resources Research Center, Shahrekord, Iran

Received on: 23 May 2012
Revised on: 5 Oct 2012
Accepted on: 1 Nov 2012
Online Published on: Sep 2013

*Correspondence E-mail: vatankhah_mah@yahoo.com

Online version is available on: www.ijas.ir

ABSTRACT

In this study 71 head of conceiving ewe and their progeny (91 head) from the flock of Lori-Bakhtiari sheep (360 head), in Sholi Station were randomly selected to determine the relationship between the immunoglobulin (IgG) concentration in the ewe's serum and colostrum, and lamb's serum. Ewe blood sample, colostrum of ewe and blood of the lamb was taken 2 weeks before parturition, 1 to 8 hours after parturition and 36 hours after birth of lamb, respectively. The serum of samples was extracted and then IgG (mg/mL) was measured in samples based on single radial immunodiffusion test and total serum protein (gr/L) based on quantitative zinc sulfate turbidity method. Results showed that the overall mean of IgG were 21.33, 48.48 and 7.86 mg/mL for blood serum of ewe, serum colostrum of ewe and blood serum of the lamb and total serum protein were 71.98, 114.48 and 65.77 g/L, respectively. The effects of age of ewe, type of parturition, gender of lamb, body condition score and body weight of ewe on considered immunity traits were not significant (P>0.05). The correlation coefficients between IgG in serum of blood and serum of colostrum in ewe and serum of blood in lamb were medium to high (0.35 to 0.75) and significant (P<0.05). The regression coefficients of IgG concentration in lamb's serum on values in ewe's serum at 2 weeks before parturition was highly significant (P<0.01) and shows that IgG content in lamb's serum increase by 0.18 units per increasing one unit in IgG content in ewe's serum. Therefore, the level of IgG in lamb's serum could be affected by the IgG concentrations in ewe's serum and colostrum. Also, the level of IgG in lamb's serum could be enhanced by improving the level of IgG concentration in ewe's serum at two weeks before lambing.

KEY WORDS colostrum, ewe serum, immunity level, lamb serum.

INTRODUCTION

The early intake of an adequate volume of colostrum of good quality is the most effective way to obtain sufficient immunoglobulin in neonates of semi-placental species such as sheep. Inadequate colostrum intake or poor quality colostrum causes failure of transfer of passive immunity (Rudovsky *et al*. 2008).

Failure of passive transfer of immunoglobulins to neonatal lambs has a significant effect on neonatal morbidity and mortality rates, and losses due to infectious diseases are possibility correlated with low concentrations of serum immunoglobulin (Ahmad *et al*. 2000).

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%). The ingestion of colostrum during the first 24-36 hour after birth is essential for the acquisition of passive immunity, because intestinal absorption of the immunoglobulin decreases rapidly and ceases by this time (Weaver *et al*. 2000). The estimates of the immunoglobulin concentration contain in colostrums which fed to the lambs are necessary for knowl-

edge of immunoglobulin levels transferred to neonatal lambs. Factors affecting immunoglobulin concentrations in the colostrum included the nutrition (O'Doherty and Crosby 1997; Mazzone *et al*. 1999), ewe body condition score (BCS) at lambing (Thomas *et al*. 1988; Al-Sabbagh *et al*. 1995), genetic and environmental factors (Gilbert *et al*. 1988). If a positive relationship was found between ewe serum and colostrum with lamb serum for IgG concentrations, the quality and quantity of IgG concentrations in colostrum may be improve by planning nutrition regimes in late gestation period and correcting the ewe BCS at lambing up to the optimum level. In the literature, a positive association has been found between density and colostral immunoglobulin concentration (0.69) for goat colostrums (Argüello *et al*. 2006) and also significant correlation between IgG levels of the ewe serum and colostrum (r=0.64) in Karakul ewes (Hashemi *et al*. 2008). In addition, Hunter *et al*. (1977) reported 0.37 and 0.34 for correlation of colostral IgG concentration with lamb serum IgG level at 8 hours and 24 hours after birth, respectively.

Lori-Bakhtiari is one of the most common native sheep breeds in the southwestern part of Iran (the Zagros Mountains), with a population of more than 1.7 million head having the largest fat-tail size among all the sheep breeds in Iran. The animals are mostly kept in villages under a semi-intensive system. The average mortality rate from birth up to 12 months of age in this breed is 1.99% per month, that disease is a major cause of lamb mortality (Vatankhah and Talebi 2009). It seems improving in immunoglobulin concentrations of colostrum by reducing the lamb mortality rate; increase the efficiency of sheep production. There is not any information about this subject matter in Lori-Bakhtiari sheep. Thus, the objective of this study was to determine the important environmental factors affecting on the immunoglobulin concentration in ewe's serum, colostrum and serum of lamb; to estimate correlation coefficients between the level of immunoglobulin in the ewe serum, colostrum and that in the lamb serum and fitting some linear regression equation to predict the immunoglobulin concentrations in lamb serum using ewe serum and colostrum.

MATERIALS AND METHODS

Data and management

The data set used in this study consisted of 71 head of conceiving ewes with different ages selected as randomly from the flock of Lori-Bakhtiari sheep with a number of 360 head, and their lambs (91 head) in Sholi station in Shahrekord, Iran.

The flock being managed under a semi-migratory, or village system (Vatankhah and Salehi, 2010). The animals were kept at the station from December to May and during this period fed alfalfa, barley and wheat stubble, indoors. The sheep grazed on natural and cereal pastures for the rest of the year. The breeding season extended from late August to late October (autumn; 20-25 ewes being assigned randomly to 1 ram) and consequently, lambing starts in late January. After weaning male and female lambs were separated. The female lambs were kept in the pasture of cultivated alfalfa, while the males were kept indoors and fed a maintenance and growth diet until 6 months of age, *ad libitum*. The diet composed of 45% alfalfa hay, 39% barley, 7% beet pulp, 8% cottonseed meal, 1% salt and mineral supplements, containing 13.5% crude protein and 2.5 Mcal/kg metabolizable energy.

Colostrum and Serum Samples

The sampling blood of ewe, colostrum of ewe and blood of the lamb was taken 2 weeks before parturition, 1 to 8 h after parturition and 36 h after birth of lamb, respectively. Blood samples without anticoagulant were taken from the jugular vein of ewes and lambs. The serum and plasma of blood samples were harvested after centrifugation and stored at -20 ˚C for further analysis in the laboratory. Colostrum and serum IgG in the samples were determined by single radial immunodiffusion was carried out in 1% agarose in PBS, pH 7.2, containing 0.5% chicken anti-sheep IgG (Nikbakht *et al*. 2008) according to the method of Mancini *et al*. (1965). Total immunoglobulin levels of samples were estimated by a quantitative zinc sulfate turbidity test (Nikbakht *et al*. 2008).

The BCSof ewes was taken at blood sampling time, based on palpation of the tips of both the spinous and transverse processes of the vertebrae, and the fullness of muscle and fat cover over and around the vertebrae in the loin region (Russel *et al*. 1961).

Statistical analysis

The normality test was assessed by application of the Kolmogorov-Smirnov-Test. The GLM procedure of SAS (1996) under the following model was employed to determine the effect of some fixed factors on the considered immunity traits (total and IgG concentrations in ewe's and lamb's serum and colostrum).

$$Y_{ijklm} = \mu + A_i + B_j + T_k + S_l + b\,(BW_{ijklm} - BW_{00000}) + e_{ijklm}$$

Where:

y_{ijklm}: is the each of the observations for immunity traits.

μ: the overall mean.

A_i: was the i^{th} age of ewe (i=3, 4, 5≥6).

B_j: the effect of j^{th} BCS of ewes at blood sampling time (j=1.0, 2.0, 2.5, 3.0, 3.5, 4.0).

T_k: being the k^{th} type of birth (k=single,twin).
S_l: is the lth sex of the lamb.
b: the linear regression coefficient of ewe body weight.
BW_{ijklm}: is the body weight of each ewe after parturation (kg).
BW_{00000}: the overall mean for ewe body weight.
e_{ijklm}: the residual effects.

Least squares means for significant (P<0.05) differences were compared using the multiple *t*-test. The CORR and REG procedures of SAS (1996) were used to determine multiple correlation coefficients between considered traits and fitting equations for estimating total and IgG concentrations in lamb's serum, respectively.

RESULTS AND DISCUSSION

The maximum and minimum of overall mean of IgG and total protein concentration observed in ewe's colostrum and lamb's serum, respectively (Table 1). These values indicated that the concentration of IgG and total protein in lamb's serum were only 16.55% and 36.85% of IgG and total protein concentration of ewe's colostrum. The least squares means of IgG and total protein of ewe's serum, colostrum and lamb's serum for different levels of some fixed factors are set out in Table 1. The effect of age of ewe and type of birth were not highly significant sources of variation in all of considered traits except for ewe's serum total protein trait which highly significant (P<0.01 and P<0.05). The least square means of ewe's serum total protein decrease with increasing the age of ewe, the differences between ewes with age 3 to 5 for this trait were not significant but significant with ewes older than 5 years. Also, least square means of serum total protein in ewes bearing to single lamb was significantly higher than ewes bearing for twin lambs (P<0.05). However, the least square means of the other considered traits were higher in ewes with single lamb than twin lambs, but the differences between them were not significant (P>0.05). The effect of sex of lamb was not significant for all of considered traits except for colostrum total protein and lamb's serum total protein (P<0.05). On the other hand, the least square means for all of the traits were higher in ewes bearing male lamb than female lamb, and male vs female lambs, but the differences between them were significant for total protein in colostrum and lamb's serum only. The concentrations of IgG and total protein in ewe's serum, colostrum and lamb's serum were not affected by BCS of a ewe. Table 1 shows that the regression coefficients for all of considered traits on ewe body weight were not significant from zero except for total serum protein in ewes which significant (P<0.05). The correlation coefficients between IgG and total protein concentration in ewe's serum, colostrum and lamb's serum are shown in Table 2. The results indicate that the content of lamb's serum IgG was highly correlated (P<0.01) with that of the ewe's serum. Also, the medium and significant (P<0.01) correlations observed between ewe's serum IgG with colostrum IgG and total protein in lamb's serum. Total protein in ewe's serum was correlated as a medium (0.23 to 0.44) to other traits. In addition, the content of IgG in colostrum was correlated to that in lamb's serum and total protein in serum lambs (0.43 and 0.25 respectively). The correlation between IgG and total protein in lamb's serum was low (0.20) but significant (P<0.05). The equations for estimate IgG concentration in lamb's serum from that in ewe's serum 2 weeks before parturition are set out in Table 3. The highly significant (P<0.01) regression coefficients of IgG concentration in lamb's serum on values in ewe's serum at 2 weeks before parturition and colostrum shows that IgG content in lamb's serum increase by 0.18 and 0.10 units per increasing one unit in IgG content in ewe's serum, and colostrum, respectively (equation 1 and 2). However, equation number 3 shows that when both IgG concentrations in ewe's serum and colostrum included in the model, the regression coefficient for colostrum was not significant from zero. The results of Table 3 indicate that equation number 1, only with IgG content in ewe's serum is sufficient (R^2=0.71) to estimate IgG content in lamb's serum, and when enter IgG content in colostrum in the model, the determinant coefficient increase by 1 percent only (R^2=0.72). The overall means of IgG content in ewe's serum and colostrum resulted in this study could be a benchmark for comparing with other breeds. The overall mean of IgG concentration in ewe's serum and colostrum in Columbia and Hampshire breeds was 21.3 and 115.1 mg/mL, respectively (Hunter *et al.* 1977). Gilbert *et al.* (1988) reported the overall mean of IgG in colostrum and lamb's serum in some breeds as 69 and 31 mg/mL, respectively, which higher than value resulted in this study for lamb's serum. In a study on the Ethiopian breed of sheep, the IgG concentration in serum of ewes with 39.6 mg/mL was higher than value in this study (Bekele *et al.* 1992). Ahmad *et al.* (2000) estimated the mean of IgG and total protein in serum of Pak-Karakul lambs 28.9 and 75.6 mg/mL, respectively, which in accordance with the value resulted for total protein in the current study. In general, the overall means for considered traits in this study are in the range reported for the other breeds (Hunter *et al.* 1977; Gilbert *et al.* 1988; Bekele *et al.* 1992; Ahmad *et al.* 2000) and the differences between them could be attributed to genetic structure, method of extracted IgG and total protein, nutrition plan, time of recording and other management factors. The first hypothesis in this research was that the level of IgG in lamb's serum could be affected by fixed factors.

Table 1 Least squares means of IgG and total protein of ewe's serum, colostrum and lamb's serum for different levels of some fixed factors

Effect	No. of observation	Ewe's serum IgG (mg/mL)	Ewe's serum total protein (gr/L)	Ewe's colostrum IgG (mg/mL)	Ewe's colostrum total protein (gr/L)	Lamb's serum IgG (mg/mL)	Lamb's serum total protein (gr/L)
Overall mean		21.33±0.44	71.98±0.90	47.48±1.66	114.48±1.72	7.86±0.35	65.77±0.90
Age of ewe (yr)		NS	**	NS	NS	NS	NS
3	21	21.50±1.13	72.00±1.74^{a}	48.54±3.32	114.41±3.89	8.32±0.75	65.52±1.89
4	18	16.68±1.12	72.06±1.62^{a}	40.31±2.83	110.05±3.31	6.26±0.71	63.87±1.75
5	16	14.01±1.14	70.85±1.91^{a}	44.24±3.74	113.40±4.50	5.97±0.88	61.29±2.19
≥ 6	16	17.29±1.14	63.54±1.91^{b}	41.63±3.74	113.14±4.40	6.37±0.88	58.92±2.19
Type of birth		NS	*	NS	NS	NS	NS
Single	51	17.29±1.10	71.70±1.38^{a}	46.61±2.55	114.83±3.03	6.80±0.61	63.18±1.52
Twin	20	17.11±1.12	67.54±1.52^{b}	40.76±2.79	109.16±3.27	6.65±0.67	61.62±1.67
Sex of lamb		NS	NS	NS	*	NS	*
Male	49	17.13±1.10	69.89±1.26	44.79±2.38	115.82±2.82^{a}	7.05±0.57	64.32±1.41^{a}
Female	42	17.11±1.10	69.33±1.39	42.57±2.56	108.17±3.04^{b}	6.41±0.61	60.48±1.53^{b}
BCS of ewe		NS	NS	NS	NS	NS	NS
2	31	18.54±1.09	71.08±1.31	43.36±2.41	111.44±2.80	7.13±0.58	63.11±1.46
3	22	17.12±1.14	68.21±1.87	46.40±3.80	112.18±4.48	6.85±0.86	62.93±2.14
4	18	15.96±1.13	69.56±1.67	41.28±3.02	112.37±3.63	6.21±0.75	61.15±1.85
Ewe's body weight		NS	*	NS	NS	NS	NS

NS: non significant; * P<0.05 and ** P<0.01.

Table 2 Correlation coefficients between IgG and total protein concentration in ewe's serum, colostrum and lamb's serum

Trait	Ewe's serum total protein (gr/L)	Ewe's colostrum IgG (mg/mL)	Ewe's colostrum total protein (gr/L)	Lamb's serum IgG (mg/mL)	Lamb's serum total protein (gr/L)
Ewe's serum IgG	0.16^{ns}	0.35**	-0.03^{ns}	0.75**	0.27**
Ewe's serum total protein	-	0.25*	0.26*	0.23*	0.44**
Ewe's colostrum IgG	-	-	0.09^{ns}	0.43**	0.25*
Ewe's colostrum total protein	-	-	-	0.09^{ns}	0.16^{ns}
Lamb's serum IgG	-	-	-	-	0.20*

NS: non significant; * P<0.05 and ** P<0.01.

Table 3 Equation for estimate IgG concentration in lamb's serum from that in ewe's serum 2 week before parturition

Equation	Regression Coefficient			
	Intercept	Ewe's serum IgG (mg/mL)	Ewe's colostrum IgG (mg/mL)	R^2
1	3.36±0.69**	0.18±0.01**	-	0.71
2	3.03±1.18**	-	0.10±0.02**	0.19
3	2.49±0.69**	0.17±0.01**	0.02±0.01^{ns}	0.72

NS: non significant; * P<0.05 and ** P<0.01.

But the results indicate that the most of fixed factors considered in this study were not affected on IgG concentrations in ewe's serum, colostrum and lamb's serum and the level of IgG in lamb's serum could not improve by correcting fixed factors at the optimum level. The age of ewe's and type of birth were not significant on considered traits except total protein in ewe's serum (P<0.05). The least square means of total serum protein in ewes decrease with age of ewe and lower in twin than single lambs significantly (P<0.05). The differences between least square means of other considered traits for various levels of ewe age and type of birth in accordance with the results reported by other investigators (Gilbert *et al*. 1988; Al-Sabbagh *et al*. 1995; Ahmad *et al*. 2000; Nikbakht *et al*. 2010).

In contrast of results in this study some investigators report by increasing the size of the litter, the concentration of IgG in colostrum increase but in the serum of lambs de crease significantly (Halliday, 1976; Halliday, 1978; Gilbert *et al*. 1988). In agreement with this study there was not any significant differences between male and female lambs for most concentrations immunity (Gilbert *et al*. 1988). Also, Bekele *et al*. (1992) similar to this study reported that the total protein and IgG concentrations in male lambs was higher than female lambs but the differences between them not significant In contrast of expected the ewe's BCS had no significant effect on immunity traits in this study. Our results are in agree with those of Thomas *et al*. (1988), who also failed to detect differences in colostral IgG concentrations in 3-yr-old Finn-Targhee ewes with a BCS of the ewe. Al-Sabbagh *et al*. (1995) reported that colostral IgG concentrations were not affected by BCS, in Polypay ewes. In the other study reported that BCS of Merino ewe's affected colostral IgG concentrations at a level of significance equal to 6 percent (p=0.06) and the highest level of colostral IgG

observed in ewe's with BCS 2.5 to 3.5 (Al-Sabbagh, 2009). My first hypothesis that state the environmental factors especially the ewe's BCS and body weight affected the concentrations of immunity traits in ewe's serum, colostrum and lamb's serum, rejected and immunity traits could not improve by handling these factors. The second hypothesis in this research was that the level of IgG in lamb's serum could be affected by the IgG concentrations in ewe's serum and colostrum and the level of IgG in lamb's serum could improve before lambing of ewe to optimum level. The results of the present study in agreement with some reports on the other breeds of sheep shown positive correlation coefficients between IgG concentration in lamb's serum with ewe's serum or colostum IgG and supported this hypothesis.

The correlation of colostral IgG concentration with the lamb's serum IgG level at 8 h and 24 h was 0.37 and 0.34 that lower than values obtained in this study (0.43) at 36 h (Hunter *et al*. 1977).

Also, Hashemi *et al*. (2008) reported that the correlation coefficient between colostral IgG and ewe's serum in Karakul ewes which higher than the value obtained in this study (0.64 vs. 0.35). The results of this study for correlation coefficients among considered immunity traits show the highest positive correlation observed between IgG in serum of lambs and ewes (0.75).

This indicates that serum IgG concentration in lambs affected by variations in the serum of ewes. Our results show that the lamb's serum IgG concentration could be estimated by measures of concentration of IgG in ewe's serum at two weeks before parturition (R^2=0.71). There is not any report about this subject matter in the literature but Rudovsky *et al*. (2008) such as results of present study found a linear association between colostral density and IgG concentration in goat (R^2=0.44).

CONCLUSION

The results of this study indicate that the fixed factors did not affect IgG concentrations in ewe's serum, colostrum and lamb's serum mostly and the level of IgG in lamb's serum could not improve by correcting fixed factors. But the level of IgG in lamb's serum could be affected by the IgG concentrations in ewe's serum and colostrum and the level of IgG in lamb's serum could develop by improving the level of IgG concentration two weeks before lambing of ewe to optimum level.

REFERENCES

Ahmad R., Khan A., Jalvi M.A. and Hussain I. (2000). The level of immunoglobulins in relation to neonatal lamb mortality in Pak-Karkul sheep. *Vet. Arhiv*. **70(3),** 129-139.

Al-Sabbagh T.A., Swanson L.V. and Thampson J.M. (1995). The effect of ewe body condition at lambing on colostral immu noglobulin G concentration and lamb performance. *J. Anim. Sci*. **73,** 2860-2864.

Al-Sabbagh T.A. (2009). Colostral immunoglobulin as affected by nutritional status in Border Licester Merino ewes deliver at Kuwait. *Global. Vet.* **3(4),** 281-285.

Argüello A., Castro N., Alvarez S. and Capote J. (2006). Effects of the number of lactation and litter size on chemical and physical characteristics of goat colostrums. *Small Rumin. Res.* **64,** 53-59.

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

Gilbert R.P., Gaskins C.T., Hillers J.K., Parker C.F. and Mc Guire T.C. (1988). Genetic and environmental factors affecting immunoglobulin G1 concentrations in ewe colostrum and lamb serum. *J. Anim. Sci*. **66,** 855-863.

Halliday R. (1976). Variations in immunoglobulin concentration in Finnish × Dorset Horn lambs. *Res. Vet. Sci*. **21,** 331-334.

Halliday R. (1978). Immunoglobulin concentration in Scottish Black face lambs on a hill farm. *Res. Vet. Sci*. **24,** 264-266.

Hashemi M., Zamiri M.J. and Safdarian M. (2008). Effects of nutritional level during late pregnancy on colostral production and blood immunoglobulin levels of Karakul ewes and their lambs. *Small Rumin. Res*. **75,** 204-209.

Hodgson J.C., Moon M., Hay L.A. and Quirie M. (1992). Effectiveness substitute colostrum in preventing disease in newborn lambs. *Occasi. Public, British Soc. Anim. Prod*. **15,** 163-165.

Hunter A.G., Reneau J.K. and Williams J.B. (1977). Factors affecting IgG concentration in day-old lambs. *J. Anim. Sci*. **45,** 1146-1151.

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

Mazzone M.M., Holocombe D.W., Ackerman C.J., Balok C.E., Mendoza Reyes A. and Hallford D.M. (1999). Effect of short-term protein supplementation on colostrum characteristics and immunoglobulin G concentrations in colostrum of ewe and lamb serum. *Sheep. Goat. Res. J*. **15,** 64-73.

Nikbakht Brujeni G.H.R., Shahi Jani S., Alidadi N., Tabatabaei S., Sharifi H. and Mohri M. (2010). Passive immune transfer in fat-tailed sheep: evaluation with different methods. *Small Rumin. Res*. **90,** 146-149.

Nikbakht Brujeni G.H.R., Tabatabaei S., Ashrafi I. and Khormali M. (2008). Antigenic similarities between camel, cattle and sheep immunoglobulin. *J. Camel. Prac. Res*. **15,** 15-19.

O'Doherty J.V. and Crosby T.F. (1997). The effect of diet in late pregnancy on colostrums production and immunoglobulin absorption in sheep. *Anim. Sci*. **64,** 87-96.

Rudovsky A., Locher L., Zeyner A., Sobiraj A. and Wittek T. (2008). Measurement of immunoglobulin concentration in goat colostrums. *Small Rumin. Res.* **74,** 265-269.

Russel A.J., Doney F.J.M. and Gunn R.G. (1969). Subjective assessment of fat in live sheep. J. *Agric. Sci. Camb*. **72,** 451-454.

SAS Institute. (1996). SAS®/STAT Software, Release 6.11. SAS Institute, Inc., Cary, NC.

Thomas V.M., McInerney M.J. and Kott R.W. (1988). Influence of body condition and lasalocid during late gestation on blood metabolites, lamb birth weight and colostrum composition and production in Finn-cross ewes. *J. Anim. Sci*. **66,** 783-791.

Vatankhah M. and Talebi M.A. (2009). Genetic and non-genetic factors affecting mortality in Lori-Bakhtiari lambs. *Asian-Australas J. Anim. Sci*. **22(4),** 459-464.

Vatankhah M. and Salehi S.A. (2010). Genetic and non genetic factors affecting Lori-Bakhtiari ewe body weight and its relationship with productivity. *Small Rumin. Res*. **94,** 98-102.

Weaver D.M., Tyler J.M., VanMetre D.C., Hostetler D.E. and Barrington G.M. (2000). Passive transfer of colostral immunoglobulins in calves. *J. Vet. Internal. Med*. **14,** 569-577.